# BUILDING CONSTRUCTION

W. B. McKAY

VOLUME THREE

LONGMANS

Aus 419435
F/O MURRAY A.R
RAAF

Allan R. Murray

# BUILDING CONSTRUCTION

By the Same Author

BUILDING CONSTRUCTION

Volumes One and Two

# BUILDING CONSTRUCTION

## VOLUME THREE

BY

W. B. McKAY, M.Sc.Tech., M.I.Struct.E.

REGISTERED ARCHITECT AND CHARTERED STRUCTURAL ENGINEER

LECTURER IN BUILDING CONSTRUCTION IN THE UNIVERSITY OF MANCHESTER
AND HEAD OF THE DEPARTMENT OF BUILDING IN THE
COLLEGE OF TECHNOLOGY, MANCHESTER

WITH DRAWINGS BY THE AUTHOR

LONGMANS, GREEN AND CO.
LONDON . NEW YORK . TORONTO

LONGMANS, GREEN AND CO. LTD.
OF PATERNOSTER ROW
43 ALBERT DRIVE, LONDON, S.W. 19
NICOL ROAD, BOMBAY
17 CHITTARANJAN AVENUE, CALCUTTA
36A MOUNT ROAD, MADRAS

LONGMANS, GREEN AND CO.
55 FIFTH AVENUE, NEW YORK

LONGMANS, GREEN AND CO.
215 VICTORIA STREET, TORONTO

*First Published* - - 1944

CODE NUMBER: 86763

PRINTED IN GREAT BRITAIN BY
LOWE AND BRYDONE PRINTERS LIMITED, LONDON, N.W.10

# PREFACE

THIS volume covers the latter portion of the syllabus in Building Construction, Stage Two, which appears on p. 136, and to which reference has been made in the preface to Vol. II.

Care has been taken to exclude from these volumes details of construction which are generally accepted as being out of date. It is not, however, always easy to distinguish between obsolete and obsolescent types. Much depends upon local practice. For example, the wood roof truss is considered by many to be obsolete, and yet king post roof trusses were adopted in some districts in a number of buildings erected just before the war. As, however, the vast post-war building programme which has to be undertaken will include the reinstatement of war-damaged property, and as many students will be engaged upon this work, it has been thought desirable to refer to one or two types of structures which, although employed extensively in the past, are now gradually falling into disuse. Hence, for example, the queen post roof truss detailed in Fig. 18 is included largely for reference purposes.

It is also realised that for some time after the war there will be a shortage of certain building materials. This applies particularly to timber, as most of it is imported, and it will be imperative that timber shall be used economically. Special attention should be given, therefore, to the description of plywood and similar products which is given on pp. 97-103, and in the production of which the rarer and more valuable timbers especially are made to go as far as possible by conversion into thin veneers.

Many alternative joinery details have been provided for comparison and selection. These include both traditional and contemporary construction, examples of the latter being the flush door and the solid-balustraded stair detailed in Figs. 25 and 35 respectively.

The homework programme on p. 135 continues and completes the one begun on p. 129, Vol. II.

The author's thanks are due to his colleague, Mr. E. Spencer, for his valuable assistance, especially in connection with the sections devoted to woodworking machinery. Thanks are also extended to the Director of Forest Products Research for permission to refer to several publications of the Forest Products Research Board, to the Controller, H.M. Stationery Office, for authority to include brief extracts from certain British Standard Specifications, and to various firms for particulars of new building materials and manufacturing processes to which references have been made in the text.

W. B. McK.

# CONTENTS


CHAPTER PAGE

I. CARPENTRY . . . . . 1

Classification, Structure, Conversion, Seasoning, Preservation, Defects, Characteristics, Uses, Preparation and Sources of Timbers—Woodworking Machinery—Doubled, Framed and Fire-resisting Floors, Determination of Sizes of Joists and Beams, and Floor Finishes—Stoothed, Trussed and Slab Partitions—Sound-proofing—Double, Laminated and Queen Post Roofs—Deep Trench Timbering—Centering.

II. JOINERY . . . . . 63

Transomed, Semicircular Headed, Glazed and Flush Doors—Semicircular Headed and Three Light Cased Windows and Metal Windows—Details of Straight Flight, Dog-leg and Open Stairs, Winders and Special Steps—Manufacture, Characteristics and Uses of Plywood, Laminboards, Blockboards, Battenboards and Composite Boards.

III. ROOF COVERINGS . . . . . 104

Manufacture and Characteristics of Clay, Shale and Asbestos-Cement Tiles and Sheets—Details of Plain, Pan, Italian and Spanish Tiling, Asbestos-Cement Sheeting, Stone Slating, Shingling, and Copper and Zinc Roofing—Thatching.

HOMEWORK PROGRAMME . . . . . 135

SYLLABUS IN BUILDING CONSTRUCTION, STAGE TWO . . . . . 136

INDEX . . . . . 137

# LIST OF ILLUSTRATIONS


| NO. OF FIG. | | PAGE |
|---|---|---|
| 1. | Structure of Hardwood and Softwood | 3 |
| 2. | Woodworking Machinery | 6 |
| 3. | Timber Kiln | 9 |
| 4. | Map showing Disposition of Principal Building Timbers | 25 |
| 5. | Woodworking Machinery | 26 |
| 6. | Saws and Rotary Cutters | 27 |
| 7. | Double and Framed Floors | 33 |
| 8. | Details of Double and Framed Floors | 35 |
| 9. | Fire-resisting Floor | 37 |
| 10. | Board, Block, Plywood, Parquet, Cork and Rubber Floor Finishes | 39 |
| 11. | Stoothed Partition | 42 |
| 12. | Trussed Partitions | 44 |
| 13, | Clay, Concrete, Plaster, Glass, etc., Partitions | 46 |
| 14. | Sound-proof Details of Floors and Partitions | 50 |
| 15. | Double Roof showing Bracing | 51 |
| 16. | Double Roof showing Trussed Purlin and Steel Beam Supports | 53 |
| 17. | Laminated Wood Trusses | 54 |
| 18. | Queen Post Roof Truss | 55 |
| 19. | Timbering of Excavations | 59 |
| 20. | Centering for Arches | 61 |
| 21. | Door with Fanlight | 64 |
| 22. | Door and Fanlight Details | 65 |
| 23. | Semicircular Headed Door | 67 |
| 24. | Glazed Doors | 69 |
| 25. | Flush Doors | 71 |
| 26. | Semicircular Headed Cased Window | 73 |
| 27. | Three Light Cased Windows | 75 |
| 28. | Metal Windows with and without Wood Frames | 77 |
| 29. | Types of Staircases | 81 |
| 30. | Straight Flight Stair | 85 |
| 31. | Details and Setting Out of Stairs | 86 |
| 32. | Dog-leg Stair | 89 |
| 33. | Balustrade Details | 90 |
| 34. | Isometric Sketch of Open-balustraded Dog-leg Stair and Details | 91 |
| 35. | Isometric Sketch of Solid-balustraded Dog-leg Stair and Details | 92 |
| 36. | Open Well Stair | 94 |
| 37. | Axonometric Sketch of Solid-balustraded Open Well Stair | 95 |
| 38. | Details of Winders | 96 |
| 39. | Details of Splayed, Bull-nosed and Curtail Steps | 97 |
| 40. | Rotary Cutter, Plywood, Laminboard, Blockboard, Batten-board, etc. | 99 |
| 41. | Plain Tiling Eaves and Ridge Details | 107 |
| 42. | Plain Tiling Hip and Valley Details | 108 |
| 43. | Vertical Plain Tiling Details | 113 |
| 44. | Pantiling Eaves and Ridge Details | 115 |
| 45. | Pantiling, Abutment, Hip, Valley and Verge Details | 117 |
| 46. | Italian and Spanish Tiling Details | 119 |
| 47. | Asbestos-Cement Sheet, Slate and Tile Details | 123 |
| 48. | Stone Slating Eaves and Ridge Details | 127 |
| 49. | Shingle Eaves and Ridge Details | 128 |
| 50. | Copper and Zinc Roofing Details | 131 |

CHAPTER ONE

# CARPENTRY

*Syllabus.*—Extended description of the classification, structure, conversion, seasoning, preservation, defects, characteristics and uses of timbers ; preparation of timber, and machines employed. Double and framed floors ; determination of sizes of joists ; floor finishes, including boards, blocks, plywood, parquet, cork and rubber. Stoothed, trussed, terra-cotta, concrete, plaster, asbestos-cement and glass partitions. Sound-proofing. Double and queen post roofs ; laminated trusses. Timbering of deep trenches and centres up to 10-ft. span.

## TIMBER

A SHORT introduction appears on pp. 55-59, Vol. I.

CLASSIFICATION.—Trees are classified (*a*) botanically and (*b*) commercially.

(a) *Botanical Classification.*—Timbers are grouped into families, each family being divided into *genera* (large classes) and each genus into several *species* (smaller classes) of trees which closely resemble each other in essential features. Thus, the classification of the pine family (botanical name *Pinaceæ*) is as follows :—

| Family. | Genera. | Species. |
|---|---|---|
| Pinaceæ (Pine) | *Abies* (firs) | *Abies alba*, white fir ; *A. balsamea*, balsam fir, etc. |
| | *Larix* (larches) | *Larix decidua*, European larch ; *L. sibirica*, Siberian larch, etc. |
| | *Picea* (spruces) | *Picea abies*, European spruce or white-wood ; *P. glauca*, Canadian spruce, etc. |
| | *Pinus* (pines) etc. | *Pinus strobus*, yellow pine ; *P. sylvestris*, Scots pine or redwood, etc. |

As shown, the Latin botanical name of each tree consists of two words, the first defining the genus to which it belongs, and the second the particular species. These names are now standard in all countries and indicate definitely the natural relationships of the timbers.

(b) *Commercial Classification.*—Timbers used commercially are divided into softwoods and hardwoods.

The softwoods are members of the conifer class or *Coniferæ*, and include the pines, firs, spruces, etc. These cone-bearing trees have needle-like leaves, and, with few exceptions, are *evergreens*. Most of the timber used for constructional work is of this class, as, in general, it is sufficiently strong for most purposes, is easily worked on account of its softness and straightness in the grain and is relatively cheap. A list of some of the principal softwoods is given in Table I, and the regions from which they are obtained are shown in Fig. 4.

The hardwoods belong to the broad-leaf class or *Dicotyledoneæ*, and include the oaks, mahoganies, beeches, birches, etc. Most hardwoods are *deciduous*, *i.e.*, they shed their leaves in autumn. They are chiefly used for decorative purposes, as for panelling, veneering and furniture, and certain of them are selected for constructional use because of their high strength and durable qualities. Table II includes a number of the many hardwoods used commercially, and their disposition is shown in Fig. 4.

As pointed out in Vol. I, whilst the division of timbers into softwoods and hardwoods is firmly established and universally recognized, it is conventional only, as some softwoods are harder than certain hardwoods.

STRUCTURE.—Wood has a complex cellular structure. The thin tubular cells vary in size and shape in different kinds of trees and their function is to (1) conduct water and soluble salts absorbed from the soil by the roots to the leaves, (2) provide storage of food during the winter and (3) give strength to the tree.

A part log is shown in diagrammatic form at A, Fig. 1. The chief structural parts are indicated at the cross, radial and tangential sections.

The diameter of the trunk and branches of a tree is increased by the addition of successive irregular concentric layers on the outside immediately within the bark. In the temperate climate of this country, and under normal conditions, a fresh ring of wood is produced yearly, and the term *annual ring* which is applied to it is therefore descriptive. In the tropics the growth does not always agree with annual periods and more than one ring may be formed annually ; the term *growth ring* is then a better description. A cross-section through a log may show a big variation in the thickness of the rings ; thus, a narrow ring formed during a droughty season may be adjacent to a relatively wide growth ring produced under better climatic conditions. An irregularity in the thickness of a ring will be caused if the tree is exposed to more sun on one side than the other.

The growing season in this country is from April to September. During this period new wood is produced by a thin layer of cells called the *cambium* and situated between the bark and the outer growth ring. These cambial cells divide and subdivide, forming new cells on the inner and outer sides. The new inner cells gradually grow into the new wood (*xylem*) and the new outer cells develop into new bark (*bast*) which conducts the food converted by the leaves to the growing parts of the tree. The wood produced at the beginning of the growing season, known as the *spring wood*, is generally of an open nature owing to the relatively large size of the cells and the thinness of their walls ; that formed towards the end of the season, called the *summer wood*, is usually denser on account of the cells being smaller and their walls thicker (see B, C and E, Fig. 1). Hence the contrasting alternate lighter and darker layers which clearly define the growth rings in many timbers. Some woods, as shown at K, do not show a sharp contrast between spring wood and summer wood.

A cross-section through a fully developed tree will, as a rule, show a comparatively dark coloured central portion or *heartwood* surrounded by a lighter coloured zone called *sapwood*. The heartwood content of a tree increases with age. Thus, the log of an immature tree is chiefly composed of sapwood, the cells of which are actively engaged in conducting mineral salt solutions from the soil to the leaves and the sap or foodstuff manufactured from them. In course of time this work is performed by the more recently formed growth rings and the cells in the inner core become inactive, the heartwood acting as a mechanical support of the tree only. Each year the inner ring of sapwood is converted into heartwood, and as an additional outer growth ring has been formed during this period, it follows that the proportion of sapwood remains practically constant. Various substances, such as gum, resin and tannin, are formed and deposited in the heartwood cells. These substances influence the colour and increase the durability of heartwood. There is no appreciable difference in strength between sapwood and heartwood.

The structure of (*a*) softwood timbers is simple compared with that of (*b*) hardwoods.

(a) *Structure of Softwoods.*—Approximately 90 per cent. of the wood consists of comparatively long, vertical (when forming the trunk) tubular cells called *tracheids*. A cross-section through a portion of a growth ring is shown at B, Fig. 1. This shows the honeycombed nature of the structure, with the tracheids arranged in rows and separated at intervals by *rays* (see next column). The tracheids are seen to be polygonal shaped when examined under the microscope. Most of them are not visible to the naked eye, and as an example the tracheid shown greatly enlarged at P is only 0·004-in. in diameter (see H). Those in the spring-wood zone have thin walls and relatively large cavities (see E, H and P), whereas the summer-wood cells have gradually diminishing cavities and thicker walls (see C and G). The function of the spring-wood cells is to conduct water to the leaves and the chief function of the summer-wood tracheids is to strengthen the tree. The cells are approximately 3-mm. (about $\frac{1}{8}$-in.) long, as shown at P ; the ends of the spring-wood cells are more rounded than those of the summer-wood cells (compare C and E). The cells communicate with each other through *pits*, of which there are many modifications. One form, known as a *bordered pit*, is shown at C and E. Pits in adjacent cells are opposite to each other and permit of the conduction of water, etc., from one tracheid to another. As shown, a pit consists of a circular area of unthickened cell wall from the border of which the wall projects to form a domical-shaped covering having a hole in the middle. The continuous thin membrane is called the *middle lamella*, and this is thickened at the centre to form the *torus* (see D). Another form of pit, called a *single pit*, is shown at N and P.

The *medullary rays*, or simply *rays*, referred to in the preceding column appear as straight, narrow, radial bands across the grain (see A and P). In softwoods they are hardly visible to the naked eye ; thus, those of redwood vary from 0·005 to 0·012-in. high. A ray consists of cellular tissue, called *parenchyma*. The cells are thin-walled and rectangular in shape. The rays are irregularly distributed, and each is usually only one cell wide and several cells high, as shown in the *tangential* section at L where the rays can be seen in section. They serve as storage accommodation for food which is transmitted through *simple ray pits* to the adjacent vertical tracheids for distribution. As shown at P, these ray pits are thin membranes which are either circular, rectangular or slit-like in shape.

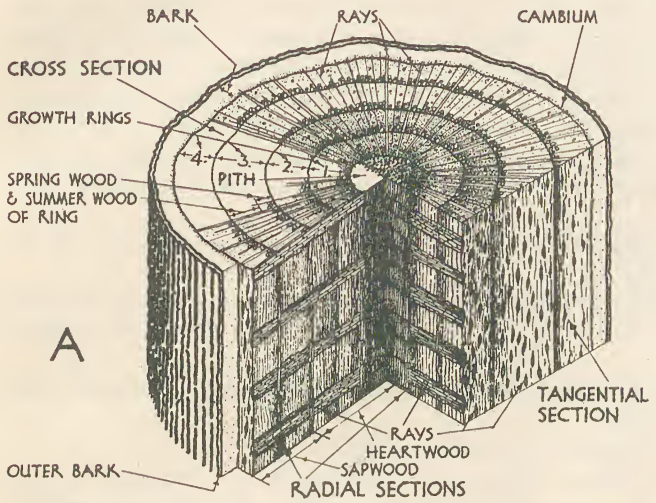
*Resin ducts* are present in certain softwoods, such as pitch pine, redwood, spruce, yellow pine and Douglas fir (see B and L). These canals are present in comparatively small numbers in the summer wood and in the rays. They receive the resin (waste product) secreted by the cells immediately surrounding them.

(b) *Structure of Hardwoods.*—This is more complicated than the structure of softwoods. It chiefly comprises vessels, fibres, parenchyma and rays.

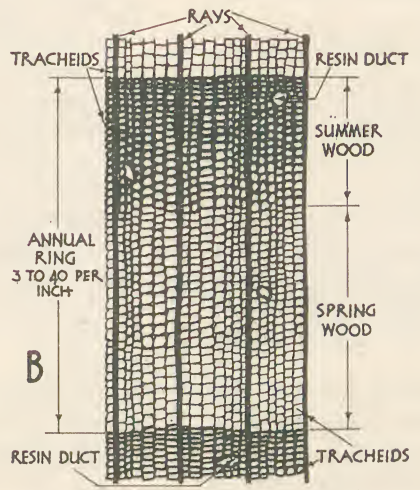
*Vessels or Pores.*—These are long vertical tubes composed of pipe-like open-ended cells which extend down the trunk. Their function is similar to that of the spring-wood tracheids of softwoods in that they conduct water from the roots to the crown of the tree. The size of the pores varies in different woods, thus a cross-section through a log of oak will show comparatively large pores which are conspicuous to the naked eye, the pores of beech are barely visible to the naked eye, and those of box are difficult to distinguish even with the aid of a magnifying glass. A pore is shown in section at M. The pits are smaller than those in softwood tracheids.

Some hardwoods, such as oak, elm and ash, have the larger pores concentrated within the spring wood and the smaller pores distributed throughout the summer wood ; these are called *ring-porous* woods, and an example is shown at J. Hardwoods in which the pores are fairly uniformly diffused (scattered) over the whole growth ring are said to be *diffuse-porous*, examples being mahogany, beech and birch (see K) ; as shown, the pores gradually decrease in size with a maximum in the spring wood.

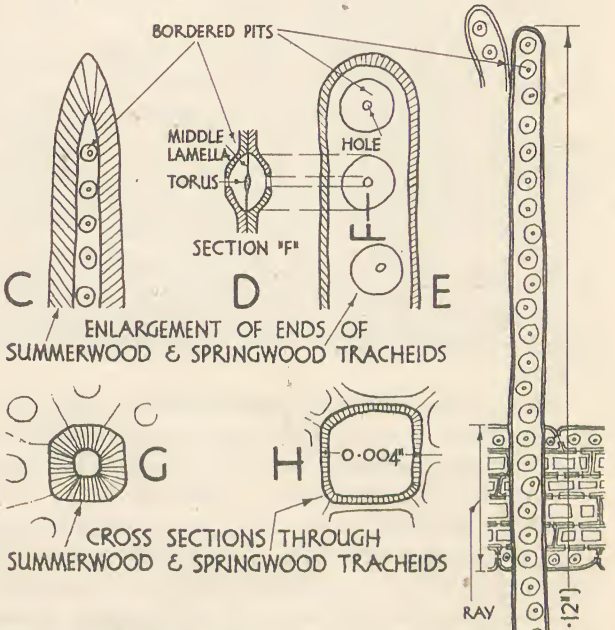
# STRUCTURE OF WOOD

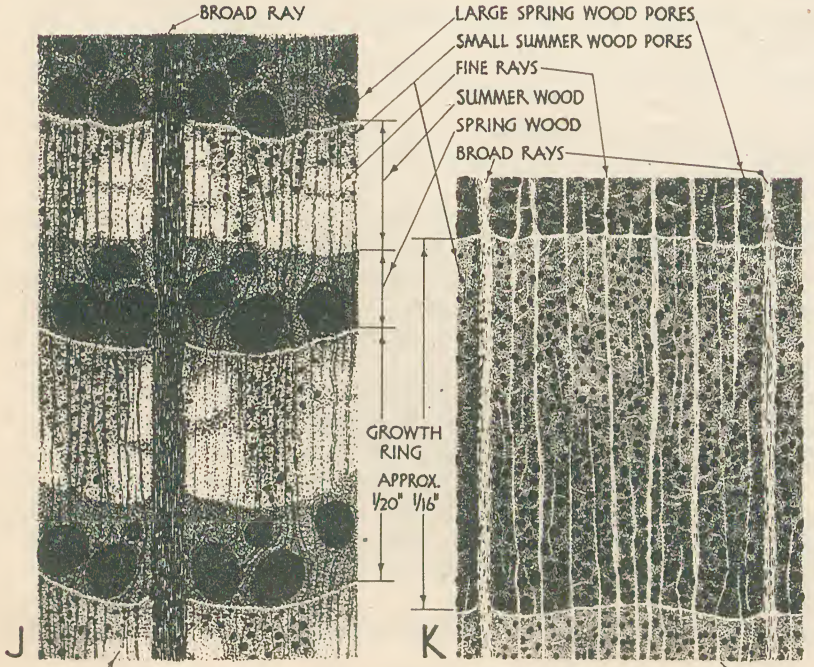



PORTION OF A LOG OF HARDWOOD

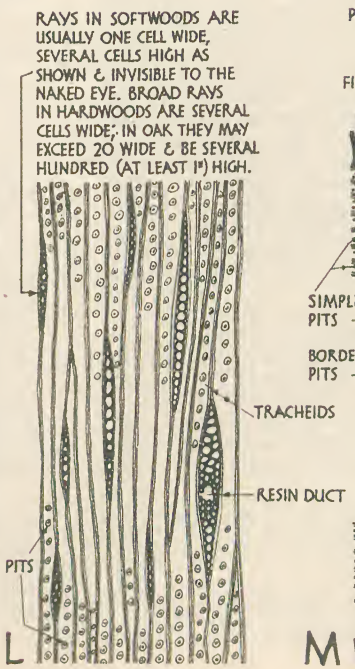



CROSS SECTION SHOWING STRUCTURE OF SOFTWOOD

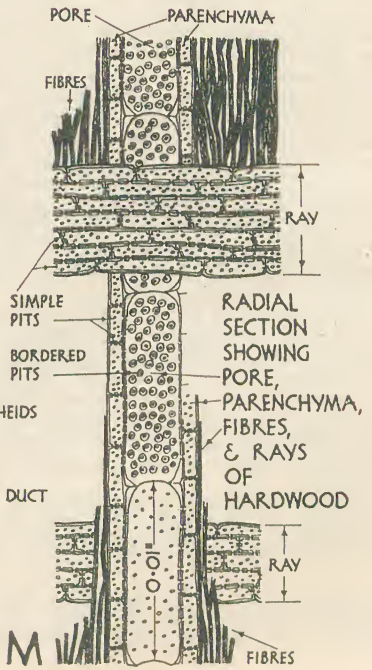



CROSS SECTIONS SHOWING STRUCTURE OF A RING POROUS HARDWOOD (OAK) & A DIFFUSE POROUS HARDWOOD (BEECH)


RAYS IN SOFTWOODS ARE USUALLY ONE CELL WIDE, SEVERAL CELLS HIGH AS SHOWN & INVISIBLE TO THE NAKED EYE. BROAD RAYS IN HARDWOODS ARE SEVERAL CELLS WIDE; IN OAK THEY MAY EXCEED 20 WIDE & BE SEVERAL HUNDRED (AT LEAST 1") HIGH.
TRACHEIDS
RESIN DUCT
PITS
L

TANGENTIAL SECTION OF SOFTWOOD SHOWING RAYS




DIMENSIONS GIVE APPROXIMATE SIZES & INDICATE MAGNIFICATION

FIGURE 1

When pores cease to act as water conductors they frequently become plugged with sac-like growths called *tyloses*.

Softwoods are without pores, and therefore *the presence of pores is a clear indication that the timber is of the hardwood type.*

*Fibres.*—These are narrow thick-walled cells, shorter (1-mm.) but somewhat resembling the summer-wood tracheids of softwoods. The bulk of the wood consists of fibres, and their function is to provide strength to the tree. They cannot be separately distinguished by the naked eye (see M).

*Parenchyma or Soft Tissue.*—This consists of thin-walled, rectangular cells occurring as vertical strands surrounding the pores (see M), as bands linking up the pores and as fine lines separating the growth rings. They are visible on cross-section as light coloured bands or patches in contrast to the darker coloured masses of fibres. The function of the soft tissue is to store reserves of food.

*Rays.*—These also store food materials. Unlike the softwood rays described on p. 2, those in most hardwoods are several cells in width. These radiating strands sometimes appear as distinct broad bands, about 15 cells wide, separated by indistinct finer rays, about 3 cells wide (as in oak and beech, see J and K), or entirely as indistinct fine rays, about 3 cells wide, as in birch. The height (as in oak) may exceed 1-in., and the characteristic " silver grain " of quarter-sawn oak is due to the presence of these very broad and high rays.

*Identification.*—The identification of the more commonly used timbers does not present much difficulty to those experienced in the industry by observing such general characteristics as the colour, texture, smell, appearance of the growth rings, rays, etc. Most timbers, however, can only be identified with certainty by a close examination of the structure of a thin cross-section (cut by a sharp knife or chisel) through a *hand lens* which has a magnification of about ten times the natural size. When more reliable information is required, as is necessary to distinguish timbers which are closely allied, it is necessary to examine prepared slides of the specimens through a *microscope* which has a magnification of twenty-five to thirty diameters. For this purpose it is necessary to examine three sections from each specimen, *i.e.*, cross, radial and tangential, the radial and tangential sections being necessary for the examination of the rays. Briefly, a slide is prepared in the following manner: A slice of the wood, about $\frac{1}{2}$-in. square and $\frac{1}{100}$-in. thick, is cut by a special knife called a *microtome*; the slice is stained by coloured alcohol and then pressed flat (mounted) on a piece of glass to which an adhesive (Canada balsam) has been applied.

The structure of a specimen should be methodically examined under the microscope. Thus, the group to which it belongs is first determined, absence of pores indicating a softwood; the size and distribution of the rays, type of pits and any resin ducts are diagnosed; if a hardwood (indicated by the presence of pores) the grouping of the larger pores (whether ring-porous or diffuse-porous) and the distribution of the smaller pores are noted, together with the character of the soft tissue, rays, etc. As the slide is being studied microscopically, a larger specimen of the wood is examined and the general features such as the colour, weight, characteristics of the growth rings, etc., are observed.

The appearance of cut surfaces of timber is influenced by its structure, and there are several terms used to express this appearance. These include (1) grain, (2) texture and (3) figure.

1. *Grain* applies to the general *direction* of the fibres and cellular units in relation to the longitudinal edges of a piece of wood or the vertical axis of a tree. There are several kinds of grain, *i.e.*, (a) *straight grain*, when the fibres are parallel; (b) *irregular grain*, when the fibres are inclined; (c) *wavy* or *curly grain*, when the fibres frequently change direction and produce alternating darker and lighter wave-like stripes on the surface (such timber when split has a corrugated surface); (d) *spiral grain*, when the fibres are arranged spirally; (e) *interlocking grain*, when the fibres in successive growth rings are inclined in opposite directions; and (f) *diagonal grain*, when straight-grained timber has been improperly converted so that the fibres are inclined to the longitudinal edges. Regarding :—

(*a*) Straight-grained timber is relatively strong and easy to work. It has only a plain figure (see p. 5).

(*b*) Irregular-grained timber is relatively weak, is difficult to work, but gives an attractive figure (see p. 5). The irregularity is often due to the presence of knots.

(*c*) Wavy or curly grained timber is highly decorative on account of the irregularly curved fibres.

(*d*) Spiral-grained timber is of reduced strength.

(*e*) Interlocking-grained timber may be subjected to excessive twisting when being seasoned, and is not easy to work. The strength is not seriously affected. The figure produced is described on p. 5.

(*f*) Diagonal-grained timber is reduced in strength owing to faulty conversion.

The term *end grain* refers to the arrangement of the exposed fibres on the cross-cut surface.

*Flat-sawn* or *plain-sawn* timber is that which has been converted (see pp. 5 and 6) so that the annual rings intersect the cut face over at *least half its width* at *less* than 45°. It is inaccurately described as " flat grain " or " slash grain." Timber can be converted quickly, cheaply and with the minimum waste by this method of conversion.

*Quarter* or *rift sawn* timber (see p. 57, Vol. I) is that which has been converted so that the annual rings intersect the cut face *in any part* at *more* than 45°. It shrinks less in width than flat-sawn timber and has less tendency to warp and split. The terms " quarter grain," " edge grain," " vertical grain " and " comb grain " are loosely applied to quarter-sawn timber.

When timber fails, due to its brittleness, it is often said to be " short in the grain." This is an inaccurate application of grain, as the condition is not affected by the direction of the fibres. Whilst it may be characteristic of certain timbers, it is also due to improper seasoning and fungoid decay, such as dry rot (see p. 14).

" Even grain " and " uneven grain " are other terms which are inaccurately used (as they are not influenced by the direction of the fibres) to describe timber whose growth rings are either uniform in width (" even ") or irregular in width ("uneven "). A more accurate expression is " growth rings of regular (or irregular) width."

2. *Texture* applies to the size and order or arrangement of the cells. Thus, a

hardwood of *coarse texture* has large pores and/or broad rays (such as oak) and that of *fine texture* (such as beech) has small pores and/or narrow rays. Examples of intermediate grades are *moderately coarse texture* (Honduras mahogany) and *medium texture* (birch). Most softwoods are fine textured on account of their small cells, and some Russian redwood is especially so. Diffuse-porous hardwoods (such as beech) and softwoods with growth rings having slight contrasting spring and summer wood (such as white pine) are known as *even-textured* timber ; ring-porous hardwoods (such as elm) and softwoods having strongly contrasting zones of spring and summer wood (such as Douglas fir) are of *uneven texture*. Sometimes softwoods are classified as " coarse grained " (or " coarse textured ") or " fine grained " (or " fine textured ") when their growth rings are wide and narrow respectively ; such expressions are not correct, as the width of rings does not affect either grain or texture ; they are best referred to as " wide " or " narrow-ringed " timbers.

3. *Figure* is the pattern on the surface of timber formed by the arrangement of the different tissues and influenced by the grain and colour. There is a big variation in the quality of the figure ; thus, straight-grained timber has only a plain figure, whereas suitably converted timber will show beautiful markings when it is irregular, interlocked or wavy grained.

The nature of the figure is affected largely by the method of conversion, and when the appearance of the timber is an important consideration, as for panelling or furniture, the form of conversion adopted should expose the characteristic elements to the best advantage. Thus, oak is quarter-sawn in order to disclose relatively large sections of the conspicuous broad rays on the cut surface and which give the richly ornamental figure known as *silver grain* ; pitch pine is flat or tangentially sawn to expose the distinct growth rings of light coloured spring wood and dark summer wood.

Conspicuous irregularities in the direction of the fibres usually give an attractive figure. The following are examples : Irregular grain due to small elevated patches on the growth rings produces *blister figure*, which is highly decorative and common to sapele and pitch pine ; the irregular grain conforming to small depressions in the growth rings gives the characteristic *bird's-eye figure* of rock maple, and the handsome figure resulting from irregular grain at the *burrs* (swellings) (see A, Fig. 40) in walnut is called *burr figure*. Interlocked grain is responsible for the *stripe figure* or *ribbon figure* peculiar to African mahogany and Andaman Padauk when quarter-sawn and for the *mottled figure* characteristic of black bean, New Zealand kaurie, etc. ; interlocked grain in Queensland maple, mahogany, sapele and other tropical timbers is sometimes irregular, and the striped figure is interrupted by longitudinal darker bands to form what is known as *roe figure*. Wavy or curly grain may produce markings in walnut, sycamore, Cuban mahogany, rock maple, Indian laurel, Australian blackwood, etc., known as *fiddle-back figure* (so called as such decorated wood is usually selected for the backs of violins) ; this is caused by alternate dense and lighter transverse bands crossing the grain.

Highly decorative figure results from converted timber obtained from just below a *crotch* (fork) (see A, Fig. 40) or at the *stump* (base) of a tree, the disturbed curly grain producing a figure in mahogany, rock maple, etc., known as *feather curl* (as it has the appearance of ostrich feathers) ; another modification as a result of contorted grain sometimes seen in oak is appropriately called *ram's horn figure*, the short waves forming a series of narrow transverse stripes.

*Ripple marks* are the transverse sections of rays seen on the cut surface of some timbers (including sweet chestnut, sycamore, East Indian satinwood and Honduras mahogany) and arranged regularly at intervals in straight lines across the width.

Variations in colour affect the figure and increase the decorative value of timber, *i.e.*, the rich colour of walnut streaked with dark bands.

*Pith-flecks* are discoloured brown streaks or spots occasionally seen in birch, Rhodesian teak, etc.

## CONVERSION

The methods of converting (" breaking down ") timber by (*a*) radial, rift or quarter sawing, (*b*) tangential, flat or plain sawing and (*c*) slab sawing are described on p. 57, Vol. I.

Machines are employed for felling trees on a large scale, although in this country most tree felling is done by hand. One type of machine used for this purpose is steam or electrically driven and resembles that shown at B, Fig. 2, with the reciprocating saw blade horizontal.

The sawing up of a log into baulks (squared timber exceeding 6-in. by 6-in.), planks (pieces from 2 to 6-in. thick and at least 11-in. wide), flitches (pieces not less than 4-in. by 12-in.), deals (pieces of softwood from 2 to 4-in. thick by 9 to under 11-in. wide), battens (from 2 to 4-in. thick by 5 to 8-in. wide), boards (under 2-in. thick by 4-in. and over in width) slices (thin wide pieces), etc., is performed by machinery. This machinery is power driven.

Whilst steam, gas and internal combustion engines are used for this purpose, the chief motive power is electricity. The power may be transmitted from its source either by shafting or, preferably, by a separate motor attached to each machine or group of machines. The shafting (steel rods) is suspended by hangers fixed to the roof or ceiling ; rotary motion is imparted to the shafting by belting which passes over pulleys connected to the shafting and the engine or motor, and the motion of the shafting is transmitted by a belt to the machine. Shafting is gradually being dispensed with as machines with individual motors are installed ; such are known as *motorized machines*.

Logs must first be cut into convenient lengths for handling. The *reciprocating cross-cut saw*, shown at B, Fig. 2, is suitable for this purpose. The mechanically operated 9-ft. long blade has a lower cutting edge, like the ordinary hand cross-cut saw, and during its reciprocating motion it cuts downwards with the inward stroke only. Logs up to 6-ft. diameter can be rapidly cross-cut by this machine.

There are several types of woodworking machines used for converting logs

# WOODWORKING MACHINERY

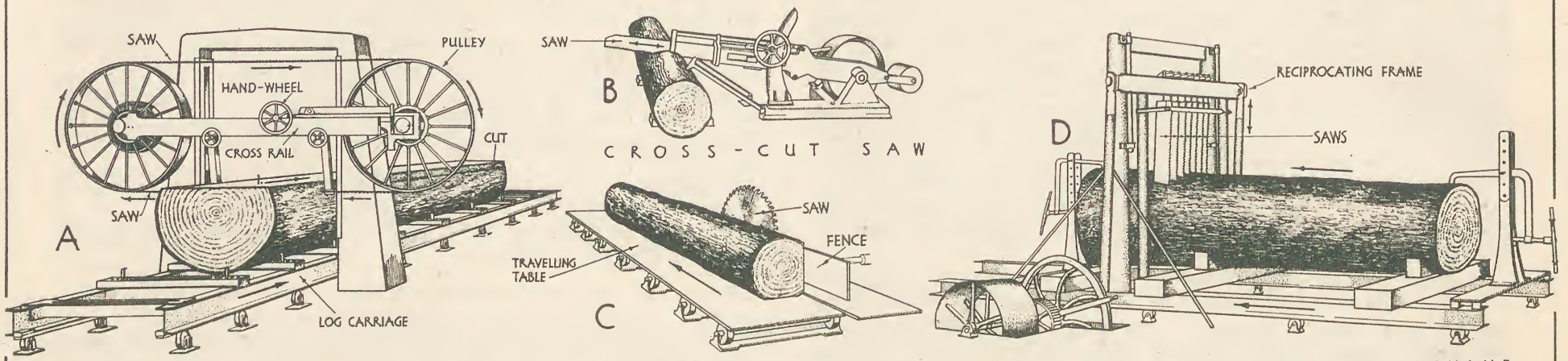



FIGURE 2

after they have been cut into suitable lengths. These include the (1) horizontal log band mill, (2) vertical log band mill, (3) circular saw mill, (4) horizontal log frame sawing machine, (5) vertical log frame sawing machine, (6) combined log and deal frame and (7) band re-sawing machine. The following is a brief description of these power-driven machines :—

1. HORIZONTAL LOG BAND MILL (see A, Fig. 2).—This consists of a 6 to 10-in. wide band or continuous saw, having teeth on one edge, which moves horizontally as indicated by the arrows, and is maintained in tension over two large (4½ to 7-ft. diameter) pulleys. The log is supported on a travelling carriage (running on wheels fixed to the floor, or the carriage may be provided with wheels which run on rails) and is fed end-on in the direction of arrow " 1." The continuous cutting action of the saw is capable of rapidly breaking down a log or baulk into panels, flitches, boards, veneers, etc., by a succession of horizontal cuts, starting from the top. The cross rail supporting the pulleys is lowered as required after each cut by manipulation of the handwheel. The rate of feed can be rapidly varied from 10 to 80-ft. per min., and the rate of return may reach 200-ft. per min.

2. VERTICAL LOG BAND MILL.—As implied, the band saw has a vertical travel over two pulleys, one above and the other below the log, as it rapidly breaks down the log by a succession of vertical cuts. A log carriage is provided. The diameter of the pulleys varies from 5 to 9-ft. and the width of the saw from 8 to 16-in. It is well adapted for quartering logs and for accurately cutting wide boards, etc., when high outputs are required.

Both the horizontal and vertical log band mills are extensively employed and are replacing other machines (such as the vertical frame sawing machine, D, Fig. 2) because of the accuracy and high speed at which logs can be broken down, under complete control, and with the minimum of waste resulting to the converted timber.

3. CIRCULAR SAW MILL (see C, Fig. 2).—This consists of a vertical circular saw (see pp. 24, 26 and 27) of 4 to 7-ft. diameter and a travelling table (running on rollers) driven by a rack and pinion to feed the log end-on against the rotating saw as it forms a vertical cut. It is also known as a *rack feed saw bench*, and is used for breaking down different-sized logs, edging flitches, etc. The rate of feed varies from 9 to 40-ft. per min., and the accelerated return of the table is 120-ft. per min.

4. HORIZONTAL LOG FRAME SAWING MACHINE.—This has a horizontal saw fixed in a reciprocating (moving to and fro) frame which cuts, in both directions of the stroke, horizontal slices off the log as it is moved forward on a metal table or log carriage end-on towards the saw. It is used for sawing logs, usually of expensive hardwoods, into boards, planks and panels where limited power only is available. The rate of feed is relatively low. The log can be examined after each cut, and thus the sawing speed can be regulated as required.

5. VERTICAL LOG FRAME SAWING MACHINE (see D, Fig. 2).—This comprises a reciprocating frame containing a number of vertical saws, spaced as required to a minimum distance apart of ½-in., which works with an up-and-down motion to convert the log into deals or boards as it is driven end-on through the frame. The saws are only effective on the down-stroke. Most softwood logs were broken down by this type of machine. Whilst several pieces are cut by one operation, the conversion is comparatively slow, and, as already stated, this machine is gradually being superseded by the horizontal and vertical log band mills and band re-saws (see below) where large outputs are required.

6. COMBINED LOG AND DEAL FRAME.—This is of a lighter but similar type to the vertical frame sawing machine D, and is used for rapidly cutting (known as *re-sawing*) deals and flitches into boards by one or more vertical saws which work with an up-and-down motion as the timber is fed by means of horizontal and vertical fluted rollers with adjustable down and side pressures. Only one deal at a time can be dealt with in the " single " type, but the " double deal frame " converts two deals at once. The saws are comparatively thin and thus a minimum wastage of wood results.

7. BAND RE-SAWING MACHINE.—This is similar to but lighter than the vertical log band mill and is designed for the rapid (up to 250-lin. ft. per min.) re-sawing of deals, flitches and battens into boards and panels with the minimum waste of wood owing to the thinness of the band saw.

Other machines are described on pp. 24-31.

## SEASONING

An introduction to this subject appears on pp. 55-57, Vol. I.

Timber from a recently felled tree contains moisture in the form of free water in the cell cavities and absorbed water in the cell walls. Seasoning or conditioning is the process concerned with the *reduction* (not total elimination) of this moisture content (" m.c.") in the timber. Timber required for internal use should be conditioned to a m.c. approximating to the average humidity of the room in which it is to be fixed (see below).

The m.c. is calculated as a percentage of the dry weight of the wood. It is determined in the following manner :—

1. A small test piece or cross-section is cut off a sample of wood before being seasoned. As the extreme ends of the piece may be drier than the remainder, it is usual to cut the cross-sectional specimen at about 1-ft. from one end in order to obtain representative figures, and its length in the direction of the grain need not exceed ½-in. The section is at once weighed (usually on a physical balance) and this is recorded as the *wet weight*.

2. The specimen is placed in an oven where it is subjected to a temperature of 100° C. (212° F.) until the whole of the moisture has been withdrawn. It is again weighed and recorded as the *dry weight*.

3. The percentage moisture is then calculated from the formula :—

$$(a)\ \text{Moisture content per cent.} = \frac{\text{wet weight} - \text{dry weight}}{\text{dry weight}} \times 100,$$

or

$$(b)\ \text{Moisture content per cent.} = \left(\frac{\text{wet weight}}{\text{dry weight}} - 1\right) 100.$$

Thus, as an example, suppose the specimen to be from a 7-in. by 1-in. floor board, ½-in. long, having an initial or wet weight of 42-gm. and a final or dry weight of 30-gm. (1-oz. approx.). The

$$\text{m.c.} = \frac{42-30}{30} \times 100 = 40 \text{ per cent.} \quad . \quad . \quad . \quad (a)$$

or

$$\text{m.c.} = \left(\frac{42}{30} - 1\right) 100 = 40 \text{ per cent.} \quad . \quad . \quad . \quad (b)$$

The determination of the m.c. in kiln samples is referred to on p. 10. The m.c. of samples of timber freshly cut from the log may vary from 50 per cent. or more for hardwoods to over 100 per cent. for softwoods. Much of this moisture must be removed, and the following moisture contents of timber required for various purposes are recommended :[1] Interior joinery work, 9 to 14 per cent. ; external joinery work (as for doors and windows), 15 per cent. ; good class carpentry work, 20 per cent. (maximum) and rough carpentry work, 25 per cent. Although the mean m.c. of timber in centrally heated buildings is approximately 12 per cent., it is advisable to reduce the m.c. in timber to be used for panelling, etc., adjacent to the heating radiators to at least 8 per cent. It is important to note that *timber which has less than 20 per cent. m.c. is not liable to become affected by dry rot* (see pp. 14-16).

[1] Full information appears in " Timber Seasoning," Forest Products Research Records, No. 4.

Defects or Degrades due to Seasoning.—The evaporation of the absorbed water in the cell walls during the process of seasoning does not commence until the whole of the free water in the cavities has disappeared. The term *fibre saturation point* is applied when the last of the free water has been removed and the cell walls are still saturated ; the m.c. at this stage varies from 25 to 30 per cent. Shrinkage does not occur until after the free water has been totally eliminated and the removal of the absorbed water commenced. Changes in size and often in shape then occur, the maximum shrinkage taking place in the tangential direction (*i.e.*, in the direction of the growth rings). Tangential shrinkage is generally approximately double radial shrinkage (*i.e.*, at right angles to the annual rings). Thus, approximate comparative figures show that the *average tangential shrinkage of timber per foot of original width increases from* $\frac{7}{10}$ *to* $\frac{9}{10}$*-in. when the m.c. decreases from 14 to 9 per cent., and the corresponding radial shrinkage increases from* $\frac{4}{10}$ *to* $\frac{5}{10}$*-in.* Longitudinal shrinkage (*i.e.*, in the direction of the grain) is almost negligible. This unequal movement in the several directions is due to the difference in structure of the wood ; thus, as the ray cells lie in a radial direction (see A, Fig. 1), and as cells do not vary appreciably in length, it follows that the presence of ray cells is chiefly responsible for the relative reduction in radial shrinkage. The thicker the cell walls the greater the shrinkage. From the foregoing it will be appreciated that : (1) Quarter-sawn timber is less liable to movement than that which has been plain sawn ; (2) denser timbers usually shrink and swell more than lighter wood ; and (3) spring wood is more static than the denser summer wood.

As stated in the preceding column, timber for internal joinery work should have a m.c. as near as possible to the mean humidity of the air in the portion of the building in which it is to be permanently fixed. Otherwise, if comparatively dry wood is exposed to a damp atmosphere it will absorb moisture and swell ; conversely, if the m.c. in the timber is relatively high and the air of the room is warm and dry, a certain amount of moisture will be evaporated and the timber will shrink. This movement or *working* takes place when the humidity of the atmosphere in a building is not constant, and serious defects may be caused by the alternating shrinkage and expansion due to extreme fluctuating atmospheric conditions. Such conditions are commonly met with in buildings in course of construction and especially during the winter months when the humidity of the atmosphere is relatively high. *It is therefore advisable to defer as long as possible the fixing of framed work, such as panelling and the laying of wood block and similar flooring, until the building has been well dried.* Every effort should be made by artificial heating and other means to dry newly constructed buildings as thoroughly as practicable before at least the more expensive woodwork is introduced.

Defects due to seasoning include checking, splitting and warping. These degrades are caused by shrinkage.

*Checking* is the longitudinal separation of the fibres which does not extend throughout the whole cross-section of the wood. It is due to unequal drying. As the moisture evaporates more rapidly from the surfaces, they tend to shrink before the inner layers, and splitting results. The various forms of checks are :—

(a) *End Checks.*—These occur on the ends, especially if the pieces are large. They are caused by the moisture evaporating more quickly through the end grain than other surfaces and the shrinkage being held back by the greater body of wood. End checking can be minimized by painting the ends ; this reduces the rate of end drying.

(b) *Surface Checks,* which form on the outer faces during the early stages of seasoning. Later they may close and are only exposed on dressing the timber.

(c) *Honeycomb or Internal Checks.*—These appear in the interior of the timber if the drying conditions are too severe in the early stages. The separation of the inner fibres is due to the shrinkage of the dried surface fibres being resisted by the wetter core, and when the internal moisture dries out later the core fibres are prevented from shrinking by the dry outer layers. A condition of stress results, known as *case-hardening*, and this produces honeycombing.

Checks are usually much shorter than shakes (see p. 58, Vol. I). The latter are not seasoning defects.

*Splitting* is the separation of the fibres which extends through a piece of timber from one face to another. Splits are sometimes called *through checks*.

*Warping.*—The various forms of this distortion are : Bow, cup, spring and twist.

(a) *Bow and Cup* are referred to on pp. 58 and 59, Vol. I.

(b) *Spring or Springing.*—This is a curvature of the edge of a piece of timber. The face is not affected and is therefore flat.

(c) *Twist or Wind.*—This is a spiral distortion (winding) along the length of a piece of timber.

*Collapse.*—This is a condition which may occur during the early stages of seasoning very wet timber which may shrink unevenly and/or excessively. The cells are flattened as a result of the partial vacuum created by the evaporation of the water and its retarded replacement by air. Collapse can be prevented if the timber is dried at low temperatures in the early stages.

*Brashness or Brittleness* may be caused to timber if it has been too rapidly dried or been subjected to high temperature in the kiln ; such timber breaks with a short fracture.

Methods of Seasoning.—There are three methods of eliminating excess moisture from timber, *i.e.*, (1) air seasoning, (2) kiln seasoning and (3) a combination of air seasoning and kiln seasoning.

1. *Air Seasoning or Natural Seasoning* (see p. 56, Vol. I).—The timber is stacked either out of doors where the piles are roughly protected by temporary sloping roofs (each consisting of a double layer of low-grade sloping boards which overhang the sides of the piles) to throw off the rain, or in an open shed having a roof and one or more walls. The site or floor should be well drained and covered with ashes or, preferably, concrete to prevent the growth of vegetation. The width of a pile varies from 6 to 12-ft., the height may be up to 16-ft. and the length depends upon that of the timber. Piles are best built on steel beams or rails supported at intervals by 9-in. square concrete or brick piers, 9-in. high, and three to four rows per width of pile ; in the absence of beams the pillars are spaced at about 2-ft. 6-in. centres. If piers are not used, the timber in contact with the floor should be creosoted.

There are several methods of piling. Thus, that shown at C, Fig. 29, Vol. I, is common for softwood baulks. A more effective arrangement, as it ensures a better flow of air, is to reduce the number of baulks in every alternate layer. The piles are sometimes arranged with the timbers inclined in the transverse direction ; any water which may enter the pile is thus effectively drained. Converted hardwood logs may be lagged or sticked as shown at E in the above Fig. 29, the logs being stacked one above the other.[1] Boards may be piled as shown in the kiln at A and B, Fig. 3 (this volume), the 1-in. *piling sticks* being of well-seasoned softwood and spaced at from 2 to 6-ft. apart, depending upon the thickness of the timber to be supported. Narrow boards are often stacked in twos with about 1-in. space between each pair.

If timber is piled in the winter the evaporation of the moisture is gradual, and excessive surface shrinkage and checking will not occur.

The rate of evaporation in air seasoning is comparatively slow in this country and is only partly controlled. The degrade, such as checking, splitting and warping (see preceding column), is relatively small because of the humidity of this climate.

Under average climatic conditions it is not possible in this country to reduce the m.c. of timber by air seasoning to much below 20 per cent., although during a prolonged spell of hot weather the m.c. may be reduced to 12 per cent. As the average reduction is not sufficient for certain internal work (see p. 7), it is clear that air conditioned timber to be used for good class joinery should be dried still further by keeping it in a heated workshop or store before being finally dressed or framed together until the required m.c. has been attained.

In order that the timber may be available for use immediately the m.c. has been reduced by air seasoning to the required percentage, it is necessary to determine the m.c. when the timber is piled and thereafter at suitable intervals. The procedure for this purpose is similar to that described for kiln seasoning and described on p. 10.

*Length of Drying Period.*—The time taken in air seasoning depends upon the temperature and humidity of the atmosphere, efficient stacking, and the thickness and density of the timber. On the average it may be taken as a guide

[1] End checks are reduced by coating the ends with paint. Strips of wood nailed across the ends of the planks (see E, Fig. 29, Vol. I) *after* shrinkage has occurred prevent the extension of any splits which may have formed ; the strips should not be fixed before contraction has taken place.

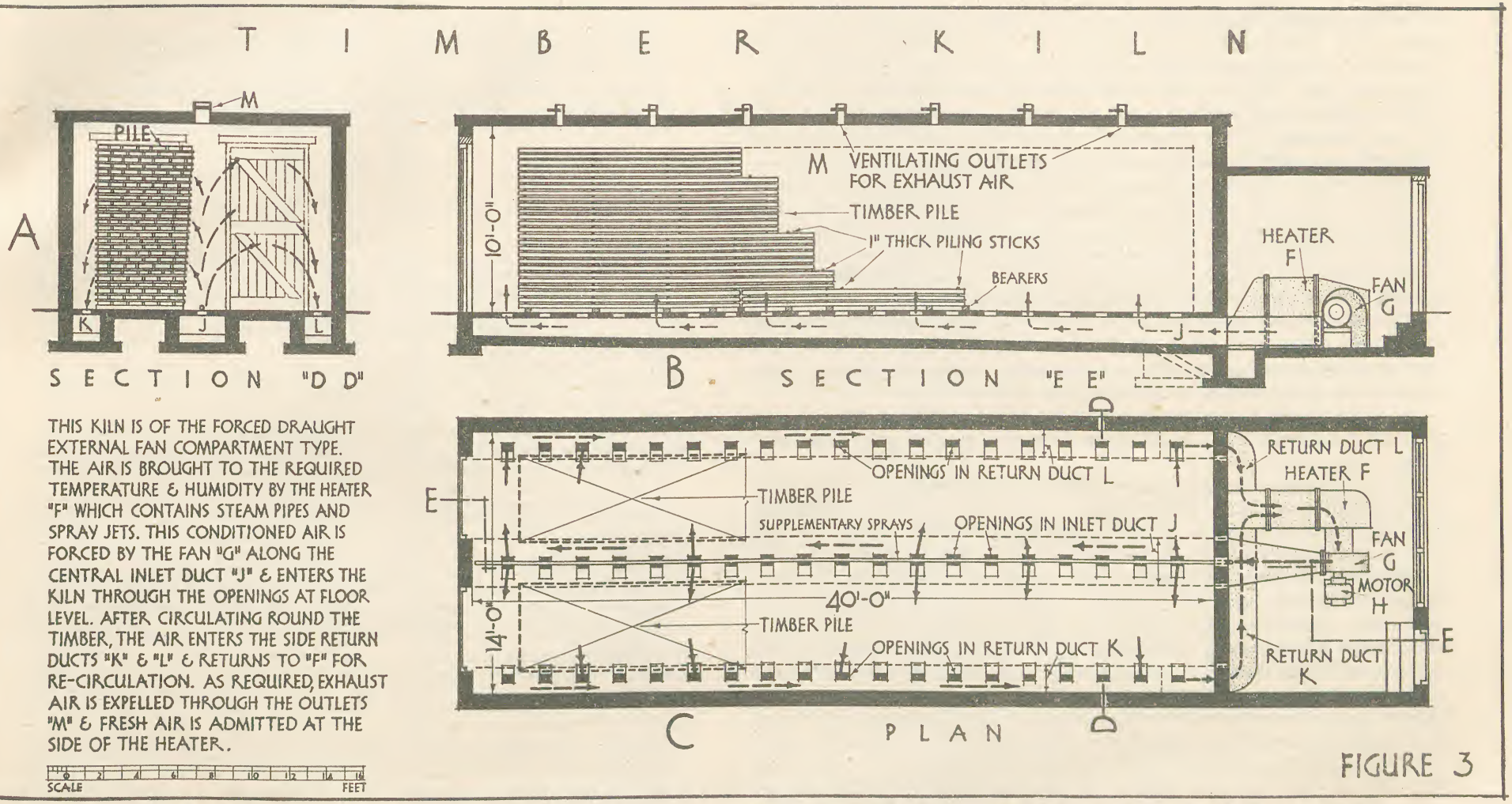

TIMBER KILN
M
PILE
A
K
J
L
SECTION "D D"
THIS KILN IS OF THE FORCED DRAUGHT EXTERNAL FAN COMPARTMENT TYPE. THE AIR IS BROUGHT TO THE REQUIRED TEMPERATURE & HUMIDITY BY THE HEATER "F" WHICH CONTAINS STEAM PIPES AND SPRAY JETS. THIS CONDITIONED AIR IS FORCED BY THE FAN "G" ALONG THE CENTRAL INLET DUCT "J" & ENTERS THE KILN THROUGH THE OPENINGS AT FLOOR LEVEL. AFTER CIRCULATING ROUND THE TIMBER, THE AIR ENTERS THE SIDE RETURN DUCTS "K" & "L" & RETURNS TO "F" FOR RE-CIRCULATION. AS REQUIRED, EXHAUST AIR IS EXPELLED THROUGH THE OUTLETS "M" & FRESH AIR IS ADMITTED AT THE SIDE OF THE HEATER.
SCALE
FEET
M VENTILATING OUTLETS FOR EXHAUST AIR
TIMBER PILE
1" THICK PILING STICKS
BEARERS
10'-0"
HEATER F
FAN G
J
B SECTION "E E"
E
OPENINGS IN RETURN DUCT L
TIMBER PILE
SUPPLEMENTARY SPRAYS
OPENINGS IN INLET DUCT J
40'-0"
14'-0"
TIMBER PILE
OPENINGS IN RETURN DUCT K
RETURN DUCT L
HEATER F
FAN G
MOTOR H
RETURN DUCT K
E
C PLAN

FIGURE 3

that the m.c. in 1-in. thick softwood boards will be reduced to 20 per cent. within two to three months, provided they are stacked in the spring, and 2-in. thick pieces will dry to a similar amount within three or four months. Hardwoods take longer to season, thus 1-in. pieces, if piled in the autumn, will take about nine months to dry to 20 per cent. m.c. and 2-in. thick hardwoods will take about a year to dry to the same amount. Any further reduction in m.c. will, of course, take longer and depends upon the store or kiln to which the timber is transferred.

The advantages of the process of air seasoning are : (1) It is relatively cheap for small supplies; (2) it requires little attention; and (3) defects due to the process are comparatively small. The disadvantages are : (1) The rate of drying is very slow ; (2) it cannot be rigidly controlled ; (3) even under favourable conditions the m.c. cannot be reduced to that required for certain internal joinery ; (4) large stacks of timber require considerable space ; (5) much capital is unproductive for a lengthy period ; and (6) damage to the timber may be caused by fungi and insects.

2. *Kiln Seasoning or Artificial Seasoning.*—This method is employed on a vast scale, as it ensures rapid drying of the timber to any required m.c. under

controlled conditions. The timber is stacked in a kiln, of which there are several types, and air, heated to the desired temperature and containing a certain amount of moisture, is circulated through the piles. The air is heated by being passed over steam pipes. This hot air, which accelerates the evaporation of moisture from the timber, must contain a certain amount of moisture, otherwise splitting and case-hardening of the wood will result owing to the rapid drying or baking of the surface before the removal of the requisite amount of moisture from the interior. The necessary humidity of the air is obtained by the admission of steam in the form of a spray, and this must be regulated carefully. Adequate circulation of the air is essential, as stagnant air would take up moisture from the timber and gradually become incapable of reducing the m.c. sufficiently Hence the air should be of uniform and sufficient velocity ; fresh air must be admitted, and saturated or exhaust air must be removed as required.

Kilns are classified into (*a*) those in which the air is circulated by mechanical means, such as fans, and known as *Forced Draught Kilns*, and (*b*) *Natural Draught Kilns* in which the circulation of the air is due to differences of temperature which cause the warmer and lighter air to rise and colder and denser air to fall.

(a) *Forced Draught Kilns* include (i) External Fan Compartment Kilns, (ii) Overhead Internal Fan Compartment Kilns and (iii) Tunnel or Progressive Kilns.

(a) (i) *External Fan Compartment Kiln.*—This is illustrated and briefly described in Fig. 3. The timber is piled as shown, the layers being separated by piling sticks, which are from 1 to 1½-in. thick and spaced at from 1 to 3-ft. apart, according to the thickness of the timber ; these sticks must be in true vertical alignment, especially if the timber consists of thin boards, otherwise the latter may become distorted. The piles are shown built up on bearers placed on the floor. Alternatively, the timber may be piled on trucks ; this is economical, as the piling is done outside the kiln and therefore little time is wasted between the removal of the trucks of dried timber and the charging of the kiln with trucks of unseasoned stuff. It is desirable to leave a 2 to 3-in. space between adjacent pieces of timber if it is thick, otherwise the boards are placed with their edges close together. The face of a pile over the inlet duct is usually inclined as shown at A, as this assists in distributing the warm air throughout the pile. The width of the piles should not exceed 6-ft. ; wider stacks make uniform drying difficult. As shown, the air is heated by steam pipes, humidified by sprays and circulated in the direction of the arrows by a fan situated outside the kiln. One difficulty is that of securing uniform circulation along the length of the kiln ; short-circuiting at the end nearest the fan is prevented by the provision of baffles along the air-inlet duct and the adjustment of the dampers at the openings in the inlet and return ducts. This is a very good type of kiln for general work.

Careful adjustment of the temperature and humidity of the air in the kiln must be made and the moisture content of the stacked timber taken at intervals during the drying process. This m.c. is determined by testing one or two representative sample boards, which are about 6-ft. long. The procedure is as follows : A small test piece is cut from a sample board and its m.c. calculated by using either the formula (*a*) or (*b*) as explained on p. 7. The m.c. of the test piece is assumed to be that of the board. The wet weight of the sample board (less the test piece) is taken at the same time and its dry weight calculated. Thus, taking the example given on p. 7 (where the m.c. of the test piece is 40 per cent.), and assuming the wet weight of the sample board is 10·5-lb., then the dry weight of the board is found from the formula (*b*), *i.e.*,

$$\text{m.c.} = \left(\frac{\text{wet weight}}{\text{dry weight}} - 1\right)100.$$

Therefore,
$$\text{dry weight} = \frac{\text{wet weight}}{\frac{\text{m.c.}}{100} + 1} = \frac{10{\cdot}5}{1{\cdot}40} = 7{\cdot}5\text{-lb.}$$

This dry weight is, of course, constant. The m.c. of this sample can now be determined at any time during the drying operation. For example, if seasoning has been in operation some time and the sample board is removed from the pile and re-weighed,

$$\text{the current m.c.} = \left(\frac{\text{current weight}}{\text{dry weight}} - 1\right)100.$$

Thus, if the current weight is 9¾-lb., the

$$\text{m.c.} = \left(\frac{9{\cdot}75}{7{\cdot}5} - 1\right)100$$
$$= 0{\cdot}3 \times 100 = 30 \text{ per cent.}$$

The drying process has thus reduced the m.c. from 40 to 30 per cent. The sample board is re-weighed at intervals until the m.c. has been reduced to that required (see p. 7 for recommended moisture contents) to complete the process.

The sample boards should be conveniently placed in the pile, and in order that they can be withdrawn readily it is usual to notch the lower edges of the piling sticks above the boards for a width slightly in excess of that of a board.

The length of the drying period and the temperature and humidity of the air depend upon such factors as the species, quality, behaviour (such as a tendency to warp) and size of the timber, and the purpose for which it is to be used. Satisfactory manipulation of the kiln is dependent upon the operator who must take these factors into consideration when regulating the supply, temperature and humidity of the circulating air to suit the changing condition of the timber, as indicated by the periodical testing for m.c. described above.

The temperature and relative humidity of the air in a kiln are ascertained by the use of a dry-and-wet bulb thermometer. The dry bulb indicates the temperature of the air, and the relative humidity is ascertained by referring the readings of both bulbs to a humidity chart or table.

The man in charge of a kiln is guided by tables or *kiln-drying schedules.* Such schedules [1] are evolved by a qualified operator as the result of his experience of handling many kinds of timbers and after taking into account the factors of species, quality, etc., stated above. On page 11 is an example of a schedule, the figures being hypothetical only.

Such a schedule is applied in the following manner : It is assumed that the timber piled in the kiln can be appropriately seasoned by adherence to the schedule and that the sample board (or the wettest of four sample boards—one on the inlet side and one on the outlet side of each pile) has a m.c. of that referred to above, *i.e.*, 40 per cent. (or between 35 and 40 per cent.). The temperature and relative humidity of the circulating air at the beginning of the drying process must therefore be 120° F. and 75 per cent. respectively, the humidity being obtained by admitting steam through the jets to the kiln until the wet bulb registers the appropriate temperature, which in this case is 112° F. The kiln must be gradually warmed up to the dry bulb temperature of 120° F. whilst the humidity is kept constant at 75

[1] Eight schedules recommended for 178 timbers appear in " Kiln-drying Schedules," Forest Products Research Records, No. 26.

| Percentage Moisture Content of Timber. | Temperature. | | Percentage Relative Humidity. |
|---|---|---|---|
| | Dry Bulb. | Wet Bulb. | |
| | ° F. | ° F. | |
| 60 | 115 | 109 | 80 |
| 40 | 120 | 112 | 75 |
| 35 | 125 | 115 | 70 |
| 30 | 130 | 117 | 65 |
| 25 | 135 | 119 | 60 |
| 20 | 140 | 121 | 55 |
| etc. | | | |

per cent.[1] This temperature and humidity are maintained until the sample board on re-weighing has its m.c. reduced to 35 per cent., when the temperature would then be raised to 125° F. and the humidity decreased to 70 per cent. When the board, after re-weighing, has its m.c. lowered to 30 per cent., the corresponding temperature and humidity would be altered to 130° F. and 65 per cent. respectively. These operations are repeated until the m.c. of the timber has fallen to the required percentage, after which the kiln is gradually cooled and the humidity increased to about 60 per cent. before the timber is withdrawn from the kiln. The maximum temperature may reach 185° F. and the humidity be reduced to 45 per cent., before the m.c. of certain timbers has been lowered to 14 per cent. Instruments for automatically recording the temperature and humidity of the circulating air may be used instead of the ordinary dry-and-wet bulb thermometer.[2]

(a) (ii) *Overhead Internal Fan Compartment Kiln.*[3]—The maximum width is 16½-ft., the maximum height (to the false wood ceiling which is suspended from the roof) is 9 ft. and the length varies from 10 to 40-ft. Uniform circulation of the hot moist air is promoted by fans fixed centrally along the length of the kiln above the false ceiling at 5-ft. intervals. The heat is provided by means of 1-in. internal diameter steam pipes which are distributed over the space above the false ceiling on both sides of the fans. A 1-in. steam spray pipe, perforated with ⅛-in. holes at 12-in. intervals and fixed centrally and immediately below the fans, provides the required moisture. The hot air is circulated from the top, down the outer sides of the stacks, through the stacks, and up between the stacks to the fans. A certain amount of the moist circulated air is allowed to escape through outlets at the roof, and fresh air is admitted at the floor level through openings in a central duct. The temperature and humidity can be automatically controlled. It is considered that this kiln is one of the most efficient and economical types.

[1] It is sometimes advocated to warm up the kiln to approximately 10° F. above the initial dry bulb temperature and maintain it for about two hours before lowering it to the initial temperature.

[2] Portable *electrical moisture meters* are now available for rapidly and conveniently determining the m.c. of timber stacked in kilns. The small electrode of one type is simply clamped to the timber and the m.c. is read directly on the dial of the meter. It is then removed. Further readings are taken as required until the required m.c. is registered on the meter.

[3] Full particulars of this kiln are given in " The Overhead Internal Fan Kiln," Forest Products Research Laboratory Leaflet, No. 10.

Another type of internal fan kiln has the fans, heating pipes and sprays below the floor level.

(a) (iii) *Tunnel or Progressive Kiln.*—This somewhat resembles the tunnel kiln used for brick-burning and described on p. 10, Vol. II, in that the kiln is in the form of a tunnel along which travel trucks piled with timber. The maximum width of the kiln is 16-ft., it is from 6 to 10-ft. high and it may be 100-ft. or more in length. It is kept filled with loaded trucks which are gradually moved forward at a uniform rate during the drying process. It is usual for one truck of seasoned timber to be removed at the discharge end and one truck of green timber to be added at the opposite end daily. Steam from sprays fixed in a duct below the floor at the discharge end provides the requisite humidity. The air, heated by steam or hot-water pipes placed below the floor for about two-thirds of its length from the discharge end, rises between the timber and circulates along the tunnel towards the inlet end before returning below the floor for re-circulation. The flow of the hot moist air in the kiln is thus in the opposite direction to the movement of the timber. Fresh air is admitted at the discharge end and mixes with the re-circulated air. The air gradually decreases in temperature and increases in humidity as it circulates round the timber towards the inlet end, and hence it is sufficiently cool and moist when it comes into contact with the unseasoned or green timber. Some of this moist air escapes at the loading end and is discharged up a chimney which produces the necessary draught to promote circulation. Alternatively, the circulation may be promoted by a fan fixed in the duct. Whilst this kiln is economical, it is best suited for drying thin timber of uniform size and quality. It is not used extensively in this country.

(b) *Natural Draught Compartment Kilns.*—This type of kiln is approximately 12-ft wide, 9-ft. high and 30-ft. long ; it has a duct below the floor extending the full width and length of the kiln. The timber may be piled as shown at A and B, Fig. 3, or it may be stacked on trucks which remain stationary during the process. A group of steam pipes for heating the air extends centrally along the duct, and the necessary humidity is provided by steam from jets immediately above it. The kiln is so called because the circulation depends upon natural means ; thus, the air after traversing the hot pipes passes upwards between the two piles and transversely through the piles, when it takes up moisture from the timber and, becoming denser, descends between the piles and the walls for re-circulation. Fresh air as required enters the duct from the outside and an equal amount of saturated air escapes at the floor level through vertical flues situated in the side walls. This simple type of kiln is very economical, but the circulation is uncertain and not easy to control. It is best suited for small-sized timber which has been partly seasoned.

3. *Combined Air and Kiln Seasoning.*—It is a common practice to reduce the m.c. of timber to approximately 20 per cent. by air seasoning before subjecting it to further treatment in a kiln. This considerably reduces the kiln-drying period (see p. 12), especially for certain hardwoods. The kiln output is therefore substantially increased.

*Length of Drying Period.*—This varies with the size, characteristics and quality of the timber. Approximately the time required in a forced draught kiln to reduce the m.c. of 2-in. thick timber from a maximum (green) to 12 per cent. is from one to two weeks for softwoods and three to twelve weeks for hardwoods. These times are increased by about half if the timber is seasoned in a natural draught kiln. Preliminary air seasoning to 20 per cent. m.c. reduces the above kiln periods to approximately one-third. These figures should be compared with those given for air-seasoning (see pp. 8 and 9).

## PRESERVATION

Decay in timber used for certain purposes can only be prevented if it is subjected to an effective process of preservation. Thus, timber required for piles, sleepers, fences and gates, wall plates and ends of floor joists built into walls, floor fillets partially embedded in concrete, weather-boarding, etc., for temporary buildings and unpainted external woodwork, should be treated with some form of preserving agent.

Fungi (plants of the mushroom tribe) are the principal cause of decay in timber used in this country (see pp. 14-16). This low form of life requires food, a certain amount of moisture and oxygen for its growth, and the absence of any one of these prevents decay. Thus the fungi cannot exist in timber if either (1) the food supply in the form of organic matter (of which timber is chiefly composed) is poisoned by a suitable preservative such as is described below, or (2) the timber is sufficiently seasoned (to a minimum m.c. of 20 per cent.—see pp. 7 and 15) and maintained in a dry condition, or (3) air is excluded (timber—such as wood piles—will not decay if kept permanently waterlogged). Fungus develops more quickly in warm weather than in cold, especially if the temperature is between 80° and 90° F.; most fungi will not grow if the temperature exceeds 105° F. or is at freezing point. In addition to fungi, much damage is done to timber by insects (see p. 16).

Effective preservation depends upon the preservative employed and its application. An efficient preservative should be poisonous to fungi and insects (but not to persons handling it), permanent, able to penetrate sufficiently, cheap and readily available; it should not corrode metal fastenings, etc., nor should the timber be rendered more inflammable by its use.

Substances used for wood preservation include (1) oil preservatives such as creosote and coal-tar, and (2) water soluble preservatives of which zinc chloride, sodium fluoride and magnesium silicofluoride are examples.

Creosote [1] is the chief preservative used and is considered to be the most effective for general application. It is a black or brownish oil, and, as stated on p. 54, Vol. II, is produced by the distillation of coal-tar. Creosote has all of the above requirements except that the inflammability is increased. It should not be used for internal woodwork if its characteristic smell is objected to. Creosoted wood cannot be painted satisfactorily.

[1] The British Standard Specification, No. 144, includes a description of the tests which may be applied to creosote.

Coal-tar as a preservative is not as effective as the creosote produced from it. Tar is less poisonous, it does not penetrate the timber because of its viscosity, it is blacker than creosote and is unsuitable for internal woodwork.

The water soluble preservatives referred to in the preceding column are not satisfactory for external use, as they are liable to be removed from the timber by rain. They are, however, very suitable for interior work, as they are comparatively odourless and colourless, and timber so preserved can be painted. They are obtained in concentrated form and require to be diluted with water to give from 2 to 5 per cent. solutions. Other preservatives of this class include mercuric chloride (corrosive sublimate) and copper sulphate, but neither is much used in this country as the former is highly poisonous to human beings, the latter is not permanent, and both have a chemical action upon metals.

There are a number of patent preservatives available. Some of these consist of poisonous chemicals (such as chlorinated phenols and naphthenic acids) dissolved in volatile oils. When such a preservative agent is applied, the oil evaporates and leaves the chemical in the timber. Their high cost limits their use.

The timber should be seasoned before being subjected to a preserving process, as the presence of moisture impedes the penetration of the preservative.

The process of preservation is just as important as the preservative, and to be effective the material must sufficiently penetrate the timber. The extent of the penetration depends upon the conditions to which the timber is to be subjected; thus, timber which is to be submerged in water or embedded in the ground should be thoroughly well impregnated with the preservative, whilst certain internal woodwork may be given adequate protection by surface treatment only. Preservatives are applied by (1) pressure, (2) non-pressure and (3) superficial processes.

1. Pressure Processes.—There are several pressure processes and these are generally adopted for treating timber on a large scale. Maximum penetration of the preservative results from pressure treatment. In each of the several methods the timber is placed in a strong steel cylinder, 5 to 10-ft. diameter and 15 to 20-ft. long, and having a tight-fitting door at each end. The cylinder is fixed horizontally at ground level, and a storage tank containing the preservative (and steam coils for heating it) is connected to it. The timber is either piled directly in the cylinder or stacked in bogies and run into it.

*Creosoting* is the principal pressure-process, and, as is implied, creosote is the preservative used. There are two methods of applying the material, *i.e.*, (*a*) full-cell process and (*b*) empty-cell process.

(a) *Full-cell Process.*—This is so called because the wood cells remain filled with the preservative after the timber has been withdrawn from the cylinder; it is also known as the *Bethel Process* (after the patentee who introduced it about a century ago). The first operation, after the cylinder has been piled with the seasoned timber and the doors have been clamped, is the reduction of the air pressure within the cylinder and the removal of the air and moisture from the

cells of the timber by a vacuum pump ; the vacuum may be up to 24-in. and is maintained for one to two hours, depending upon the size and species of the wood. The cylinder is then completely filled from the storage tank with creosote which has been heated to a temperature varying from 100° to 180° F., and a pressure of approximately 100-lb. per sq. in. is applied and maintained for about two hours until the required quantity of creosote (as determined from the measuring instruments on the storage tank) has been forced into the timber. The amount of creosote absorbed depends upon the kind and condition of the timber and the use to which it is to be put, and varies from 3-lb. (for some hardwoods) to 12-lb. per cub. ft. (for certain softwoods). Finally, the pressure is released, the creosote is drained off, and a vacuum is again applied to withdraw excess creosote from the timber before it is removed. This method is best suited for piles and timber which is to be fixed in wet positions, and where exudation of the creosote from the wood (known as " bleeding ") is not objected to.

(b) *Empty-cell or Rueping Process.*—This is very suitable for treating timber required for building purposes, as it is effective, the wood is clean to handle on account of the small amount of bleeding which takes place, and it is comparatively cheap, as it only requires approximately 50 per cent. of creosote used in the full-cell process. The timber in the cylinder is first subjected to a pressure of about 40-lb. per sq. in. of compressed air. This pressure is maintained whilst the heated creosote is admitted and the cylinder has been completely filled, after which about 10-lb. per sq. in. additional air pressure is applied for approximately fifteen minutes. This causes the creosote to enter the cells of the timber and compresses the air already in them. The pressure is then released and thus allows the compressed air in the timber to expand and expel much of the creosote from the cells. A partial vacuum is finally applied and this removes more creosote from the timber. The cells are therefore free from preservative although their walls have been well coated with the creosote.

Creosoting by the non-pressure process is described in the next column.

*Burnettizing.*—Patented by Burnett a little over one hundred years ago, this pressure process is still fairly extensively employed. It is somewhat similar to creosoting, except that the preservative is zinc chloride, one of the water soluble salts referred to on p. 12. The seasoned timber, after being subjected in the cylinder to a vacuum for about an hour, is impregnated with the solution (1-lb. of the salt to 5-gals. of water) at a pressure of approximately 100-lb. per sq. in. The process takes about five hours to complete. It is cheaper than creosoting, but is less effective on account of its lack of permanence. Open tank treatment (see next column) is also resorted to.

The *Boucherie* pressure process (in which unseasoned timber was impregnated with a solution of copper sulphate) and the *Carbolizing* or *Blythe's* process (which consisted of injecting creosote vapour and superheated steam into the timber, followed by creosoting) are not now employed.

2. Non-Pressure Processes.—The treatment is known as *steeping*, or *soaking* or *open tank*, and is adopted for relatively small quantities of timber when a pressure plant is not available. The apparatus simply consists of a rectangular watertight tank, open at the top, and from 2½ to 5-ft. wide, 3 to 3½-ft. deep and 12 to 15-ft. long ; a cylindrical storage reservoir of similar capacity is sometimes provided in addition. There are three methods, *i.e.*, (*a*) hot-and-cold steeping, (*b*) hot steeping and (*c*) cold steeping.

(a) *Hot-and-cold Steeping.*—This is the most efficient of the non-pressure processes. The open tank is preferably sunk in the ground to within a few inches from the top to facilitate loading and unloading of the timber ; the storage reservoir is fixed adjacent to it and at ground level. Provision for heating the preservative in the open tank must be made. This preferably takes the form of steam coils resting on the bottom of the tank and protected by horizontal bars which support the timber ; alternatively, the tank is fixed on top of a furnace having a horizontal flue extending the full length of the tank and terminating with a chimney stack.

Briefly, the preserving operation is conducted in the following manner : The *seasoned* timber is stacked in the tank and held down by bars at the top ; cold preservative, usually creosote, is run into the tank from the reservoir, gradually heated to about 200° F. and maintained at this temperature for one to two hours, after which it is allowed to cool (by turning off the steam or drawing the fire), the liquid is pumped back into the reservoir, and the timber is removed. During the heating period the air in the cells of the timber expands and some of it is expelled ; as the preservative cools, the air left in the timber contracts and the partial vacuum created causes the liquid to be gradually absorbed into the timber. Whilst not absolutely essential, the provision of the reservoir does make it possible for the timber to be drained before removal and reduces the loss of preservative whilst making the timber less objectionable to handle. The operation only takes a day to complete.

An improvement on the above method is effected if, after cooling, the contents of the tank are re-heated and the timber is left to soak in the hot preservative for an average period of two hours before removal. This causes much of the creosote absorbed during the cooling period to be expelled from the timber and thus results in an economy of preservative used.

The ends of fence posts are effectively preserved by *butt treatment*, for which only a metal barrel or drum, placed upon a crude fireplace, is required. The posts are placed vertically in the drum with their pointed ends immersed to the required depth in the cold creosote which is heated and then cooled as above described. Hot creosote is poured or brushed over the upper portions of the timber whilst it is being soaked. To meet bigger demands, a long tank, sub-divided into compartments to assist in keeping the posts upright, may be used.

Ends of floor joists which are to be built into walls may also be protected by butt treatment in a similar manner. The apparatus may be either a drum or a small tank, a useful addition being a pair of scaffold poles, fixed in the ground at each side, to which a short cross-piece is lashed at a convenient height to afford a support for the upper ends of the joists during treatment

(b) *Hot Steeping*.—This process has been largely superseded by hot-and-cold steeping, as the latter is more efficient, occupies less time and is more economical. As is implied, the method consists of soaking the timber in a tank of hot preservative for a varying period, depending upon a number of conditions, such as the species, proposed use, etc.

(c) *Cold Steeping*.—This is not now advocated, it being even less effective than hot steeping on account of the slow penetration of preservative which takes place. The rate of absorption varies, but an immersion of one week per inch thickness of timber may be regarded as an average approximation.

*Kyanizing Process*.—This is seldom adopted in this country, as the preservative, mercuric chloride (corrosive sublimate), used in the process is extremely poisonous and therefore dangerous to workmen handling it. The timber is steeped in a 1 per cent. solution of mercuric chloride which is contained in a wood trough, as the preservative has a corrosive action upon metal.

*Powellizing* or *Powell Wood-process*.—The preservative used in this patent open-tank system is a heated solution of which the chief ingredient is sugar. The timber may be either seasoned (if required for internal woodwork or furniture) or unseasoned (for fencing, sleepers, etc.). The apparatus consists of a long (up to 100-ft.), open tank or chamber with removable ends. The timber is piled on trolleys and run into the tank, the ends are clamped (which make the tank watertight), the solution of required strength is introduced and heated by steam pipes, and after several hours' application this liquid is removed, the unloading door is unclamped and the timber is withdrawn. Neither pressure nor vacuum is required as the saccharine solution is readily absorbed by the timber. The process is very efficient. It is adopted chiefly in those countries where creosote is unobtainable and especially where sugar is grown. It has not been employed extensively in this country.

3. Superficial Processes.—These include (*a*) dipping, (*b*) spraying and (*c*) brush application. None of these surface treatments is as effective as the pressure and open-tank systems, as the preservative only slightly penetrates the timber. The wood must be seasoned, and the surface should be dry before application. Greater penetration generally results if the preservative is applied hot, especially if creosote is used.

(a) *Dipping* is the best surface treatment, except for timber already fixed in position. The pieces of wood are simply dipped in a receptacle containing the preservative ; the longer the immersion the better.

(b) *Spraying*.—The preservative is applied in the form of a fine spray as it is forced through the nozzle of the appliance by compressed air. It is an effective form of surface treatment, as a liberal amount of the solution can be applied and the pressure makes possible the penetration of any cracks and crevices.

(c) *Brush Application*.—This is the most common method of treating existing exposed woodwork with creosote or other preservative. The liquid should be applied liberally with the brush and any cracks in the timber should have special attention. At least two good coats should be given, the first coat being allowed to dry before the second is brushed on. Where accessible the treatment should be renewed every three years, especially if it is external work such as fencing, weather-boarding, timber outbuildings, etc.

Fire-retarding.—Whilst timber cannot be made fireproof, there are several chemical solutions and proprietary paints available for rendering it fire-resisting. One of the most effective fire-retardants is ammonium phosphate. The material is applied by any of the methods described for preservation. The timber should be well seasoned before treatment in order that maximum penetration may be effected.

## DEFECTS

Defects due to seasoning are referred to on pp. 7 and 8. Other defects are described on p. 58, Vol. I. Defects caused by fungi and insects are described below.

It has been stated on p. 12 that fungi are the chief cause of decay, that the development of fungus is dependent upon food, moisture and oxygen, and that the absence of one of these prevents decay. A suitable temperature is also essential for fungoid growth. The principal decay of building timber is dry rot.

Dry Rot.—This disease, which is highly infectious, causes a tremendous amount of destruction in timber. The decay is caused by several fungi, that most frequently found in buildings being the *Merulius lacrymans*. Partially seasoned wood fixed in a warm, damp and badly ventilated position is very liable to attack by this fungus. The spores (germs or seeds) of the fungus develop under the above favourable conditions and minute silky hollow threads or tubes (called *hyphæ*) are thrown out. These rapidly spread over the surface of the wood as an open network or as a closely interlaced covering or sheet which is grey coloured, relieved with blue and/or yellow patches. Under very damp conditions especially, the hyphæ may be arranged in cotton-wool like masses ; such a collection is known as a *mycelium*, and its colour is snowy-white with occasional bright yellow patches. In course of time the mycelium develops into a tough, fleshy substance called a *fruit body*. Each of these " mushroom " growths may exceed 1-ft. in diameter ; it is of a brown or dark red colour with a white edge, and its surface resembles a sponge, it being corrugated and pitted with small holes. Countless numbers of spores are produced on the surface, and these can be readily conveyed by air currents, rats, mice and insects and thus infect timber far removed from the original site. The disease can also be spread by infected tools and clothing. The fungus produces drops of water which hang from its surface, hence the derivation of its specific name *lacrymans*, which means " weeping." Another property of this fungus is its ability to produce white or grey coloured strands which spread in all directions over timber, brickwork, plaster and steel, and may pass through mortar joints and actually penetrate thick walls consisting of soft bricks or stone. These strands, which may be up to $\frac{1}{4}$-in. thick, are capable of conveying water from the damp original site of the dry rot to comparatively dry timber, remotely situated, thereby providing suitable conditions for the extension of the disease. Dry rot is transmitted from one floor to another in this manner and so may spread to every part of a building if the attack is vigorous and the conditions suitable.

During the development of the fungus the hyphæ attack the fibres of the wood and feed upon the substance of the cell walls, which are gradually broken

down. The decayed wood becomes friable and falls to powder under pressure by the fingers, it is dry (hence the name applied to the rot), the surface becomes uneven, and cracks extend both with and across the grain to divide it into *cubical* pieces. The colour is brown or dirty red, the wood is reduced in weight, it has little strength and the member ultimately collapses. Sometimes the decay is entirely internal and there is no external evidence of it.

*Prevention.*—The following precautions should be taken to prevent timber from becoming affected by dry rot.

1. All timber should be sound, well-seasoned stuff of good quality. It is important to note that timber having a moisture content of less than 20 per cent. is unlikely to become attacked by the disease (see p. 7), and therefore all timber required for building purposes should not exceed this percentage of moisture content. Timber may have become infected during storage in the holds of ships or when piled in timber yards, but adequate kiln seasoning destroys such infection.

2. The timber must be kept dry, hence an additional reason why dampness in buildings must be avoided. The absence of efficient damp proof courses and site concrete has been a frequent cause of dry rot in ground-floor timbers ; dampness due to defective eaves gutters, fall-pipes, roof coverings and drains may cause decay. Gutter and flat-roof timbering has also been subjected to rot because of the penetration of moisture through parapet walls. Infected firewood stored in damp cellars or similar accommodation may be the means of introducing the decay. Built-in timbers, such as wall plates, ends of floor joists etc. (especially if the walls are of cavity construction—see p. 43, Vol. II), should be adequately treated with a preservative ; embedded wood fillets used in solid flooring (see Fig. 9, and B and C, Fig. 10) must be thoroughly preserved (preferably under a pressure process—see p. 12), and the whole of the concrete should be covered with bitumen of a minimum thickness of $\frac{1}{8}$-in. before the floor boards are fixed. A narrow band of bitumen should be applied to one face of an internal wall which has a solid floor on one side and an open wood floor on the other.

3. Adequate circulation of fresh air round all timbers must be provided, as stagnant moist air is particularly favourable to the growth of dry rot. Provision must therefore be made for sufficient *through* ventilation under all wood floors, especially ground and basement floors (see Fig. 32, Vol. I, and C, Fig. 20, Vol. II). The air bricks or gratings should have sufficient clear opening area (the British Standard Specification, No. 493, requires a minimum total unobstructed area of one-fifth area of air brick), and a minimum of $1\frac{1}{2}$-sq. in. of open area per foot run of wall should be allowed ; this is obtained if 9-in. by 6-in. air bricks are provided at 6-ft. intervals. Dead pockets of air must be avoided and cross-currents of air must be induced, hence the need for honeycombed sleeper and partition walls to allow the air currents through the vents in the outer walls to be unobstructed. If a solid floor prevents this (such as a concrete scullery floor at the rear of a wood living-room floor) it is advisable to embed 3 or 4-in. diameter horizontal drain pipes during the laying of the concrete floor at 6-ft. intervals between openings in the division wall and ventilators in the outer back wall. An air brick or opening must be provided at each angle to obtain free circulation at the corners. Through ventilation under wood floors of halls and corridors is often omitted and is a frequent cause of dry rot. Air spaces round ends of built-in floor joists should be provided (see S and U, Fig. 32, Vol. I). This also applies to the lower ends of roof rafters, as extensive damage to roof timbers at the eaves has been caused by solid beam-filling (especially when the walls are thick and leaks through the roof covering have caused dampness) preventing the circulation of air round the timber. Dry rot to wall panellings and skirtings is also caused by dampness penetrating through outer walls, affecting the plugs and grounds and spreading to the back of the exposed woodwork.

4. Site concrete should be well brushed and pieces of wood, shavings, etc., removed before the boarding of ground floors is fixed. Outbreaks have been traced to affected debris of this description which is liable to dampness. Trench and concrete sub-floor setting-out pegs should also be removed.

5. Linoleum and similar covering should not be laid on new wood floors, especially wood-covered concrete floors, before they have had time to dry out.

*Detection and Remedial Measures.*—Dry rot may be recognized by the presence of any or all of the following symptoms : (*a*) The appearance of the fungus described on p. 14 ; (*b*) warping, "cubical rot" (caused by cracks—see preceding column) and other signs of infected timber already referred to ; (*c*) decay or collapse of timber members (the backs of skirtings and the underside of floor boards may be extensively decayed—the latter being readily broken by stamping the heel on them) ; (*d*) an objectionable musty smell indicating dampness ; and (*e*) a deposition of red-coloured powder (which teems with the spores) below a floor.

The curative measures necessary to eradicate the disease depend, of course, upon its extent. Drastic steps must be taken in serious cases, and the various operations must be thoroughly and carefully carried out if a recurrence and extension of the disease are to be prevented. Thus, taking a bad case as an example, the following would be the sequence of operations if an examination of a ground floor disclosed the decay to be extensive and general.

1. The whole of the timber is removed. This includes the skirtings, floor boards, joists, wall plates, plugs and grounds ; it may also be necessary to splay-cut and remove the feet of architraves. This decayed or unsound timber is carefully taken outside and immediately burnt. Any plaster behind which the fungus may have spread must also be removed.

2. The faces of the walls below the floor, including the timber pockets and the surface of the site concrete are well cleaned down with a wire brush. These sweepings, in which the spores of the fungus will be present in countless numbers, are carefully conveyed to and spread over the wood fire and destroyed.

If no site concrete exists (and there are many buildings without it), the top 4-in. or so of the earth is excavated, removed and buried ; this earth is probably teeming with the spores which have fallen from the affected timber, and its removal should therefore be done with care to prevent droppings providing

sources of infection. For the same reason, care should be taken to prevent spores being carried about on the feet to other parts of the building. Sometimes the penetration of the fungus into the sleeper walls is such as to necessitate their demolition and removal. The removal of such walls and the top soil is, of course, done before the main walls are brushed down.

3. Sterilizing the surfaces of the walls and site concrete now follows. This consists of applying a plumber's blow-lamp to the *whole* of the brushed surface. This destroys the spores, provided the flame when applied slowly and for a sufficient time renders the surfaces hot to the touch. To ensure complete success, however, it is advisable to follow this heat treatment by an application of a reliable antiseptic solution, which should be liberally applied in two coats. An antiseptic which is recommended is a 4 per cent. solution of sodium fluoride (6-oz. of the crystals being dissolved in 1-gal. of cold water); a 5 per cent. solution of magnesium silicofluoride ($\frac{1}{2}$-lb. of the salt per gallon of water) is also effective. Neither mercuric chloride (corrosive sublimate) nor zinc chloride (blue vitriol) is now advocated, as the former is dangerous to handle and the latter is only moderately efficient.

4. Necessary structural work, such as the insertion of a horizontal damp proof course, the provision of air bricks or grates and holes in division walls to ensure adequate *through* ventilation (see p. 15), the construction of sleeper walls and the laying of site concrete, is carried out.

5. Finally, the new floor timbers, skirtings and feet of architraves (finished with splayed joints) are fixed. The timber must be sound, well-seasoned stuff of good quality. The joists, underside of floor boards, backs of skirtings, wall plates, plugs and grounds should be treated with a preservative (see p. 12). Creosoting is the most effective treatment, but any of the water-soluble preservatives (sodium fluoride, etc.) may be used if the smell of creosote is objected to.

The above operations are costly and are only called for when the decay is widespread. In a mild case it may be only necessary to remove the decayed timber (together with at least 1-ft. of the adjacent sound wood) and replace it with sound preserved stuff after brush-treating as much as possible of the existing timber with preservatives. Every suspected case must be closely examined and dealt with on its merits. Any doubtful source of infection must be removed, otherwise the disease will again develop and further expense will be entailed. Experience shows that partial treatment only is a waste of money and materials, as subsequent extensive operations are usually necessary to effect a permanent cure.

Another species of fungus which produces dry rot in building timbers is *Coniophora cerebella* or Cellar Fungus. It only attacks wet timber, and the decay is usually confined to cellar, bathroom, etc. floors where there has been a leakage of water, and to leaky roofs. *Coniophora* presents a less serious problem than *Merulius*, as decay caused by it is at once arrested if the cause of the dampness is attended to and the timber is allowed to dry. The decayed wood is much darker than that caused by *Merulius* and the cracks are mainly with the grain. The strands of this fungus are brown or almost black, bunches of the mycelium are absent, the hyphœ may produce small patches of yellowish skin, and fruit bodies are rarely seen in buildings. The characteristics of the two species are thus different.

Insect Attack.—Wood-boring beetles are the insects which cause most damage to timber in this country, and of these the (1) Death-watch Beetle, the (2) Common Furniture Beetle and the (3) Lyctus Powder-post Beetle are the most important.

1. *Death-watch Beetle* (*Xestobium rufovillosum*).—These chiefly attack well-matured hardwoods in old buildings; softwoods and recently seasoned timber are rarely affected. The beetles lay their eggs in cracks and holes in the wood; white larvæ (grubs) which hatch out of the eggs are about $\frac{1}{4}$-in. long when full-grown, and after boring in the wood for one and a half or more years develop about August into pupæ (chrysalis) near to the surface of the wood; whilst the winged beetle is formed within a few weeks after pupation, it does not issue from the wood until the following spring. Much destruction is caused during the larval stage, as the grubs bore numerous tunnels of about $\frac{1}{8}$-in. diameter in the timber and produce dust during the process. In advanced cases most of the interior of the affected wood members are reduced to powder. Many thousands of pounds have been expended within recent years upon restoring oak roofs of churches and other ancient buildings (*e.g.*, Westminster Hall) which have been damaged very extensively by the ravages of the death-watch beetle.

The conditions of dampness and poor ventilation associated with dry rot are also conducive to attack by the beetle. Hence any treatment of infested structural timbers must include the provision of adequate general ventilation and air spaces round built-in ends of members, and the remedy of defects causing dampness. Badly infected timber must be removed and replaced by sound stuff free from sapwood. There are a number of proprietary insecticides on the market which are claimed to eradicate the beetle. The timber must be well brushed down and vacuumed to remove as much dust as possible before the solution is liberally applied by means of a brush or spray, and several applications are necessary to ensure sufficient penetration; creosote is sometimes used when discoloration and smell are not objected to. Such treatment should be renewed every three or four years.

2. *Common Furniture Beetle* (*Anobium punctatum*).—These attack both hardwoods and softwoods, and especially old unpolished furniture and panelling. The life-cycle and damage caused are somewhat similar to those of the death-watch beetle, except that common furniture beetles emerge from the wood in the summer, and the diameter of the bored holes is about $\frac{1}{16}$-in.

Insecticide treatment, as described above, is applied to prevent further damage by this beetle.

3. *Lyctus Powder-post Beetles* (*Lyctidæ*).—Grubs of these beetles cause extensive damage to furniture, internal joinery work such as panelling, and timber

piled in yards. The sapwood only of certain comparatively newly or partially seasoned hardwoods (including ash, elm, oak and walnut) is subject to attack; softwoods are immune, and well-matured hardwoods in old buildings are not affected. The presence of holes (up to about $\frac{1}{16}$-in. in diameter) on the surface of the wood, and small piles of flour-like dust cast out from the holes (hence the name of the beetle), are characteristic of infected timber. The beetles emerge from the wood during the spring and summer; eggs are laid in the pores of the sapwood and are hatched out within a fortnight into white larvæ or grubs (about $\frac{1}{4}$-in. long when fully grown), and these develop into pupæ and, finally, beetles which issue from the timber within one to two years after the larval stage.

There are several proprietary solutions available for treating infested timber and which are brush-applied to the surface during the spring and summer, but such insecticides are ineffective unless several applications are made. Proper seasoning of the timber destroys any *Lyctus* present, but frequent inspection of it should be made when stacked in the yard in order that any re-infestations may be detected.

## CHARACTERISTICS AND USES OF TIMBER

There are several hundred species of commercial timbers. A selected number of softwoods used in this country are classified in Table I, and some hardwoods are listed in Table II. The map shown in Fig. 4 shows the distribution of most of these timbers and may be a convenient reference. A large proportion of these selected species are grown either in the British Isles, and known as *Home-grown Timbers*, or within the British Empire and specified as *Empire Timbers*.[1]

A few of the characteristics and uses are also given in these tables. The weight of timber varies with the moisture content and the proportion of wood tissue to voids; the greater the m.c. the greater the weight. The weights given in the tables are the average when the m.c. is 15 per cent. The m.c. also influences the strength of timber, and well-seasoned wood is stronger than that in the green condition. Thus, for example, the maximum compressive strength of pitch pine increases from approximately 3,700 to 7,500-lb. per sq. in. as the m.c. decreases from 75 (its green condition) to 12 per cent.

[1] These are listed in "A Handbook of Home-grown Timber" and "Empire Timbers," both publications of the Forest Products Research Laboratory.

TABLE I

SOFTWOODS

| Standard Name. | Botanical Name. | Source. | Weight (lb. per cub. ft.). | Characteristics. | Uses. |
|---|---|---|---|---|---|
| Cedar, Western Red (Pacific red cedar) | *Thuja plicata* | British Columbia, Western U.S.A. | 24 | Reddish brown, weathering to silver grey; distinct growth rings; straight grained, easy to work; very durable, brittle; stains, paints and enamels well. | General carpentry and joinery; decorative work, including panelling; roof shingles. weather-boarding. |
| Fir, Douglas (British Columbia, Columbian and Oregon pine) | *Pseudotsuga douglasii*<br>*P. taxifolia* | British Columbia, Western U.S.A.<br>British Isles | 33 | Pink to light reddish brown; well defined growth rings and prominent figure; straight grained with tendency to wavy or spiral grain; difficult to work, strong; available in large sections and long lengths; stains but does not paint well. | "Clear grade": first-class joinery, as for doors, windows, panelling, plywood, floor boarding and blocks.<br>"Merchantable grade": carpentry. Home-grown (of inferior quality): rough boarding. |
| Hemlock, Western (grey fir) | *Tsuga heterophylla* | British Columbia, Western U.S.A. | 31 | Pale brown; distinct growth rings and good figure; usually straight grained, fairly even textured; not durable when subjected to alternate dry and wet conditions; stains, paints and enamels well. | General joinery; best quality for decorative work, including panelling and furniture; flooring. |
| Kauri, New Zealand (Kauri pine) | *Agathis australis* | New Zealand | 38 | Pale yellow to light brown; straight and interlocked grain producing mottled figure; strong, very durable; works easily; stains, paints and polishes well. | Good-class joinery, including floor boarding and blocks; mottled varieties for panelling, etc. Limited supply. |
| Kauri, Queensland | *Agathis palmerstonii* | Queensland, Australia | 30 | Similar to, but softer than, N.Z. Kauri. | Good substitute for N.Z. Kauri. |
| Larch, European | *Larix decidua* | Europe, including British Isles | 37 | Reddish brown heartwood, yellowish white sapwood; distinct growth rings; straight grained; very durable, tough and strong; resinous; difficult to work; stains and paints satisfactorily. Most valuable home-grown softwood. | Carpentry and heavy construction; fencing, gates, wood buildings, piles, sleepers, scaffolding. |

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE I—*continued*

SOFTWOODS—*continued*

| STANDARD NAME. | BOTANICAL NAME. | SOURCE. | WEIGHT (lb. per cub. ft.). | CHARACTERISTICS. | USES. |
|---|---|---|---|---|---|
| Pine, Jack (Banksian pine) | *Pinus banksiana* | Canada, Northern U.S.A. | 31 | Similar to red pine (see below); inclined to be knotty. | Inferior carpentry, sleepers, boxes and crates. Similar to low-grade redwood (see below). |
| Pine, Pitch . . . | *Pinus palustris* | Southern U.S.A. | 41 | Light red; very distinct growth rings with large proportion of summer wood which gives bold effect, occasionally has an attractive blister figure; straight grained; very strong and durable, resinous, which affects ease of working; even textured; obtainable in long lengths; subject to heart shakes; grain tends to show through paint; varnishes well. | Good-class general carpentry and joinery; church and school furniture, office fittings, piles. |
| Pine, British Honduras Pitch (slash, Cuban and Nicaraguan pine) | *Pinus caribœa* | Central America, West Indies. | 44 | Similar to pitch pine. | Similar to pitch pine. |
| Pine, Red (Canadian, Ottawa and Quebec red pine) | *Pinus resinosa* | South-Eastern Canada, Northern U.S.A. | 33 | Light red or reddish yellow heartwood, creamy white sapwood; generally straight grained, easily worked to a smooth silky finish; fairly durable; paints and stains well. | Similar to redwood. |
| Pine, Siberian (Manchurian and Korean pine) | *Pinus sibirica*, etc. | Siberia, Manchuria | 26 | Similar to yellow pine (see below). | Internal joinery. A good substitute for yellow pine. |
| Pine, Sugar . . . | *Pinus lambertiana* | California, U.S.A. | 28 | Resembles Canadian yellow pine (see below). | General internal joinery. |
| Pine, Western White (finger cone and mountain pine) | *Pinus monticola* | British Columbia, North-Western U.S.A. | 28 | Similar to yellow pine, but growth rings are narrower and it is slightly harder and stronger. | Similar to yellow pine (see below). |
| Pine, Yellow (Canadian white, Canadian yellow, Ottawa white, Quebec, Weymouth and white pine) | *Pinus strobus* | Eastern Canada, U.S.A. | 26 | Pale straw to light reddish brown; growth rings indistinct; soft, straight grained, even textured, easily worked to a smooth silky surface; moderately durable; stains, paints and polishes well. | Good-class general internal joinery; first quality expensive and now used chiefly for pattern-making, carving and similar special work. See Siberian pine. |
| Redwood (Scots pine or fir in British Isles, northern pine, red deal, yellow deal, Memel fir, Norway fir, Polish fir, Swedish pine, Baltic redwood) | *Pinus sylvestris* | British Isles, Norway, Sweden, Finland, Poland, Northern Russia | 33 | Pale reddish brown heartwood, light yellowish brown sapwood; distinct growth rings; straight grained, easily worked to a clean finish; very durable when preserved; tough, strong, moderately resinous; stains, paints and polishes well. | Extensively used for general carpentry and joinery. Quality not so reliable as formerly, as less care taken in selection of trees, and Douglas fir is often preferred for first-class work. |
| Spruce, Canadian (white, Quebec and New Brunswick spruce) | *Picea glauca* (white)<br>*P. mariana* (black)<br>*P. rubra* (red) | Eastern and Northern Canada, Eastern U.S.A. | 28 | White; growth rings distinct; straight grained and easily worked, but knots liable to give trouble; not durable; stains, paints and varnishes well; red variety has reddish tinge and more pronounced figure. | Better qualities used for cheaper joinery; roughest grade used for shuttering, scaffolding, packing cases. |
| Spruce, Sitka (silver spruce) | *Picea sitchensis* | British Columbia, Western U.S.A., British Isles | 29 | White to pink; mostly straight grained, occasionally spiral grained; easily worked when free from knots, with satiny finish when planed; tougher and superior in quality to better grades of Canadian spruce; obtainable in large sizes; stains, paints and polishes well. | Imported: good-class carpentry and joinery.<br>Home-grown: temporary work such as shuttering. |

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE I—*continued*

SOFTWOODS—*continued*

| STANDARD NAME. | BOTANICAL NAME. | SOURCE. | WEIGHT (lb. per cub. ft.). | CHARACTERISTICS. | USES. |
|---|---|---|---|---|---|
| Whitewood (white deal or fir, European spruce, northern and Baltic whitewood) | *Picea abies*<br>*Abies alba* | Northern and Central Europe, British Isles | 27 | Yellowish or pinkish white ; distinct growth rings ; straight grained ; presence of many hard black knots affects working ; smooth silky finish ; stains, paints, varnishes and polishes well. | Internal carpentry and cheaper joinery.<br>Rougher grades (including home-grown) : temporary work, packing cases. |
| Yew . . . . | *Taxus baccata* | British Isles | 42 | Orange-brown heartwood, white sapwood ; distinct growth rings ; straight and irregular grained, producing attractive figure ; strong, hard, durable ; stains and polishes well. | Limited supply available for doors, panelling, floor blocks, furniture, gates. |

TABLE II

HARDWOODS

| STANDARD NAME. | BOTANICAL NAME. | SOURCE. | WEIGHT (lb. per cub. ft.). | CHARACTERISTICS. | USES. |
|---|---|---|---|---|---|
| Ash<br>(American and Japanese ash) | *Fraxinus excelsior*<br>*F. americana*<br>*F. mandshurica* | British Isles<br>Eastern Canada, U.S.A.<br>Japan | 44 | White to light brown ; ring porous, large pores distinct ; growth rings distinct, rays indistinct ; straight and coarse grained and occasional decorative burrs ; very tough and elastic, not durable when exposed ; stains, varnishes and polishes well. American and Japanese similar but inferior to home-grown. | Figured timber for decorative work, furniture, veneers, plywood. Chiefly for hammer, etc., shafts, hockey, etc., sticks, motor, etc., body framework. |
| Avodiré<br>(olon, appayia) | *Turræanthus africanus* | Gold Coast, Ivory Coast | 35 | Golden yellow ; growth rings not visible, rays indistinct ; straight and interlocked grain producing rich mottled figure ; tough, strong, elastic. | Veneers, plywood, panelling, cabinet work. Used as a substitute for mahoganies (p. 21). |
| Balsa . . . . | *Ochroma* | Central America, West Indies | 7-10 | Pinkish white with silky lustre ; soft and spongy. Lightest of commercial timbers. | Sound and heat insulation. |
| Basswood<br>(American lime) | *Tilia glabra* | Canada (Quebec, Ontario and New Brunswick), U.S.A. | 26 | Creamy white to light brown ; fine texture ; not durable when exposed. | General interior joinery ; bent plywood cores. |
| Bean, Black . . . | *Castanospermum australe* | Australia | 49 | Dark brown streaked with greyish brown ; usually straight grained, but sometimes interlocked, giving a beautiful mottled figure ; durable ; rather difficult to work. | Panelling and decorative work, both solid and as a veneer. |
| Beech<br>(American beech) | *Fagus sylvatica*<br>*F. grandifolia* | British Isles, Central Europe<br>South-East Canada, North-East U.S.A. | 46 | White or pale brown ; diffuse porous, pores barely visible ; growth rings moderately distinct, rays very distinct as flecks ; straight grained, fine texture, works easily ; hard and very durable if wet or dry ; stains and polishes well. | Block and parquet flooring, furniture, doors, piles, wood-working tools such as plane stocks and mallets. |
| Beech, Southland . . | *Nothofagus menziesii* | New Zealand | 36 | Pinkish brown with silky lustre ; growth rings fairly distinct, rays invisible ; usually straight grained and fine texture ; not durable when exposed ; stains and polishes well. | As above. |
| Birch . . . . | *Betula pubescens* (white)<br>*B. pendula* (silver) | Europe, including British Isles | 42 | White to light brown ; diffuse porous, pores barely visible ; growth rings and rays barely visible ; fairly straight grained, medium texture ; strong, tough ; not durable ; cuts with smooth, bright surface. | Plywood, doors, furniture, motor bodies. |

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE II—*continued*

HARDWOODS—*continued*

| STANDARD NAME. | BOTANICAL NAME. | SOURCE. | WEIGHT (lb. per cub. ft.). | CHARACTERISTICS. | USES. |
|---|---|---|---|---|---|
| Birch, Canadian Yellow (American, Quebec, black, curly and yellow birch) | *Betula lutea* | South-East Canada, Newfoundland, North-East U.S.A. | 44 | Light to dark reddish brown; straight grained with occasional curly grain; fine texture; tough, hard wearing but not durable when exposed. Japanese birch similar. | Plywood, flooring, furniture; aeroplane construction. |
| Blackwood, Australian | *Acacia melanoxylon* | Australia, Tasmania | 45 | Golden or reddish brown with darker streaks; straight and wavy grain (fiddle-back); even texture; strong, durable; polishes well. | High-class joinery, including panelling, cabinet work, veneers. |
| Cedar, Central American (British Honduras, Mexican, Nicaraguan, Trinidad, West Indian and cigar-box cedar) | *Cedrela mexicana* | Central America, West Indies | 30 | Closely related to true mahogany (*Swietenia*, see p. 21); light red; ring porous, large pores visible; growth rings and rays barely visible; straight grained, occasionally figured, but ripple marks usually absent; characteristic scent; easily worked, durable; readily stains and polishes well. | Panelling, furniture; best grades for similar purposes to Honduras mahogany; cigar boxes. |
| Chestnut, Sweet (Spanish chestnut) | *Castanea sativa* | Europe, including British Isles | 35 | Light brown heartwood, sapwood lighter; ring porous; resembling oak, but rays not visible and therefore silver grain figure of oak is absent; splits readily; subject to heartshake. | Fencing, gates, piles; figured timber for decorative work. |
| Chestnut, American | *Castena dentata* | U.S.A. | 35 | Similar to, but coarser than, sweet chestnut. | Similar to sweet chestnut. |
| Ebony | *Diospyros ebenum* | Ceylon, India | 74 | Black, or black with brown stripes; growth rings and rays invisible; fine and even texture; very hard and durable; very difficult to work; polishes well. | Inlaying (to panelling, etc.), veneers, cabinet work, piano keys, etc. |
| Ebony, African | *D. crassiflora* | East Africa | 70 | | |
| Ebony, Macassar | *D. macassar* | Celebes | 64 | | |
| Elm (English, Dutch, wych and white elm) | *Ulmus procera* (English) | British Isles | 35 | *English:* reddish brown (*wych*, paler with green streaks); ring porous, large pores distinct; growth rings and rays distinct; irregular grain producing attractive wavy figure and coarse texture; tough; difficult to work; durable under water; wych is strongest; *white* is usually straight grained and not durable when exposed. | Weather-boarding, furniture, piles, flooring (white). |
| | *U. hollandica* (Dutch) | | 35 | | |
| | *U. glabra* (wych) | | 43 | | |
| | *U. america* (white) | Eastern Canada, Eastern U.S.A. | 39 | | |
| Eng (In) | *Dipterocarpus tuberculatus* | Burma | 55 | Dull greyish brown; fairly straight grained, sometimes interlocked; hard, strong, durable; not easy to work. | Carpentry, flooring, window sills. Cheap substitute for teak (p. 23). |
| Gaboon (okoumé, Gaboon mahogany) | *Aucoumea klaineana* | Gabon, Spanish Guinea (West Africa) | 27 | Light pinkish brown (paler than true mahogany—*Swietenia*); diffuse porous, pores visible; growth rings indistinct, rays invisible; straight and interlocked grain; not durable when exposed; easily worked; difficult to stain, but takes a good polish. | Veneers and plywood; cheap furniture, and as inferior substitute for mahoganies. |
| Greenheart | *Ocotera rodiœi* | British Guiana, North Brazil | 65 | Olive green heartwood, pale yellow sapwood; straight grained; very strong, tough, durable and difficult to work; tendency to split; highly resistant to attack of sea-worms. | Heavy construction and marine work (as dock gates, piers, piles), stair treads, fishing rods, shafts of golf clubs. |
| Greywood, Indian Silver (white chuglam) | *Terminalia bialata* | Andaman Isles, India | 43 | Yellowish brown with irregular dark markings producing attractive marbled figure; straight grained; strong, tough, moderately durable; stains and polishes well. | Superior decorative work such as for panelling, furniture, interior fittings, veneers, plywood. |
| Guarea (black guarea) | *Guarea thompsonii* | West Africa | 40 | Related to true mahogany (*Swietenia*). *Guarea:* pinkish brown (not so dark as Honduras mahogany); diffuse porous, pores just visible; growth rings and rays invisible; straight and wavy grain with mottled figure, fine texture, easily worked; characteristic cedar-like scent. *Scented Guarea:* similar, but slightly darker; more scented and texture less fine. | Superior joinery, panelling, veneers, furniture. Substitute for mahoganies. |
| Guarea, Scented (white guarea) | *G. cedrata* | | 38 | | |

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE II—*continued*

HARDWOODS—*continued*

| STANDARD NAME. | BOTANICAL NAME. | SOURCE. | WEIGHT (lb. per cub. ft.). | CHARACTERISTICS. | USES. |
|---|---|---|---|---|---|
| Gurjun (apitong, kanyin, keruing, yang) | *Dipterocarpus turbinatus* | Andaman Islands, Burma, Ceylon, Siam, Malaya, Sarawak, Philippine Islands | 46 | Red to dull greyish brown; straight and interlocked grain, resinous; not easy to work; hard, durable. | General constructional work, flooring, bridge decking, wagon building. |
| Hornbeam | *Carpinus betulus* | Europe, including British Isles | 43 | White; usually cross-grained; difficult to work; very hard, strong and tough. | Flooring, mallets, mill-wheel cogs. Limited supply. |
| Iroko (odum, African teak, mvule) | *Chlorophora excelsa* | West and East Africa | 41 | Light to dark brown; interlocked grain producing ribbon figure; coarse but even texture; strong, very durable. | Superior joinery (doors, windows, staircases, flooring, panelling), furniture. Substitute for teak. |
| Jarrah | *Eucalyptus marginata* | Western Australia | 56 | Reddish brown heartwood, lighter sapwood; generally straight grained, sometimes interlocked; very hard and durable; may contain gum veins which affect workability; will take excellent polish, staining not required. | Carpentry, flooring, stair treads, counter tops, piles, fencing, marine work, bridge decking. |
| Karri | *Eucalyptus diversicolor* | Western Australia | 59 | Similar to jarrah; slightly paler in colour and less durable. | Similar to jarrah. |
| Kokko (East Indian walnut) | *Albizzia lebbek* | Andaman Islands, Ceylon, India | 40 | Dull brown with darker streaks; somewhat resembles true walnut (see p. 24). | Superior decorative work, including panelling and furniture; veneers. |
| Lauan, Red<br>Lauan, White | *Shorea negrosencis*<br>*Pentacme contorta* | Philippine Islands | 35 | Pale to dark reddish brown; diffuse porous with distinct pores and white chalky resin ducts; straight and irregular grain producing roe or stripe figure. Allied to mahoganies. | Substitutes for mahoganies. Plywood. |
| Laurel, Indian | *Terminalia tomentosa* | Burma, Southern India | 54 | Light walnut brown to deep chocolate; straight and irregular grain, attractive figure by dark wavy streaks; coarse texture; hard, very strong and durable; not easy to work. | Superior solid and veneered panelling, furniture. |
| Lignum Vitæ | *Guaiacum officinale* | West Indies, Tropical Africa | 78 | Dark greenish brown, nearly black; interlocked grain, fine and uniform texture; very hard and durable; very difficult to work. Heaviest commercial timber. | Turnery, mallet heads, truncheons, bowls ("woods"), electrical work (insulators). |
| Lime | *Tilia vulgaris* | Europe, including British Isles | 35 | White to pinkish yellow; growth rings and rays not very distinct; fine uniform texture, soft and easily worked. | Wood carving, turnery, furniture, parts of musical instruments. |
| Mahogany, African (Accra, Benin, Duala, Cape Lopez and Lagos mahogany) | *Khaya ivorensis*<br>*K. anthotheca*<br>*K. grandifoliola* | West Africa<br>West Africa and Uganda<br>West Africa | 30-45 | Light pinkish brown to deep red; diffuse porous, pores distinct with gum deposits; growth rings not visible, larger rays just visible; straight and interlocked grain producing roe and striped figure; moderately durable; polishes well. | Good-class joinery, including panelling, veneers, plywood, furniture and similar decorative work. |
| Mahogany, Cuban (Spanish, West Indian, Porto Rico and Jamaican mahogany) | *Swietenia mahagoni* | West Indies | 40-50 | Rich reddish brown; diffuse porous, distinct pores often containing white deposits; straight, interlocked, irregular and wavy grain producing variety of handsome figure such as blister, roe, stripe and fiddle-back; ripple marks may be present but not so distinct as Honduras mahogany; fine texture; strong; shrinks and warps little; high polish readily obtained. Is a true mahogany. | Superior joinery and decorative work, such as panelling, veneers and furniture. Most valuable of the mahoganies, but very expensive and more difficult to obtain. |
| Mahogany, Honduras (baywood, Central American mahogany) | *Swietenia macrophylla* | British Honduras, etc., Central America, Brazil, Peru | 34 | Similar to Cuban mahogany but colour usually lighter and texture not so fine; ripple marks distinct; dark-coloured gum deposits in pores common, white deposits rare; strong, durable, works easily; takes a good polish. Is a true mahogany. | High-class joinery, including panelling, furniture, veneers and similar decorative work. |

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE II—*continued*

HARDWOODS—*continued*

| STANDARD NAME. | BOTANICAL NAME. | SOURCE. | WEIGHT (lb. per cub. ft.). | CHARACTERISTICS. | USES. |
|---|---|---|---|---|---|
| Makoré (cherry mahogany) | *Mimusops heckelii* | West Africa | 40-50 | Pale pinkish brown to purplish brown; straight and interlocked grain producing rich mottled figure with occasional dark veins; polishes well. | Good-class decorative work such as panelling, veneers and furniture. Excellent substitute for the mahoganies. |
| Maple, Queensland (silkwood) | *Flindersia brayleyana* | Queensland, Australia | 39 | Light brown; similar to gaboon (p. 20), but darker, and interlocked grain produces a beautiful stripe figure. | Panelling and decorative work, including veneers, furniture. |
| Maple, Rock (bird's-eye, blister, curly, fiddle-back, hard, sugar and white maple) | *Acer saccharum* | South-East Canada, North-East U.S.A. | 46 | Light yellowish-brown; growth rings distinct as dark lines, rays distinct; straight, irregular and wavy grain producing bird's-eye, blister and fiddle-back figure; dense, tough, hard, strong, not durable; difficult to work; stains, paints, enamels and polishes well. | Flooring, stair treads, panelling, veneers, furniture. |
| Meranti, Red | *Shorea acuminata*, etc. | Malaya | 36 | Similar to lauan (p. 21). | Substitutes for mahoganies. Plywood, veneers, interior joinery. |
| Meranti, White (yellow meranti) | *S. bracteolata* | Sarawak | 35 | | |
| Myrtle, Tasmanian | *Nothofagus cunninghamii* | Tasmania; Victoria, Australia | 46 | Similar to Southland beech. | Similar to Southland beech (p. 19). |
| Oak (English, pedunculate, sessile, durmast, Austrian and Polish oak) | *Quercus robur* (*pedunculata*) *Q. petræa* (*sessiliflora*) | Europe, including Great Britain | 43-53 | *English*: Heartwood light yellow-brown to deep warm brown (known as "brown oak" when the colour has been deepened by a fungus), sapwood lighter; ring porous, spring wood pores distinct; growth rings distinct, very distinct broad rays give characteristic beautiful "silver grain" effect when rift-sawn; very durable, tough and strong; gallic acid present corrodes ironwork; polishes well. Best of species. *Austrian* (Wainscot): Straighter grained than English and therefore slightly less distinctive figure. *Russian* (Riga, Memel, etc.) and *Polish* (Volhynia): Stronger than Austrian but not so well figured; easier to work and cheaper. *Durmast* (France): Less strong and durable than English. | Decorative and superior joinery (figured varieties), including panelling, veneers, plywood, furniture; carpentry such as open roofs, beams; fencing, posts, gates. English supply limited. |
| Oak, American Red | *Quercus rubra*, *Q. borealis*, etc. | Eastern Canada, U.S.A. | 46 | *White* oak somewhat similar to English oak and preferred to *red* oak which is usually coarser and inferior; reddish brown heartwood sharply defined from nearly white sapwood, colour not uniform. | As above, but for inferior work. |
| Oak, American White | *Q. alba*, etc. | | 48 | | |
| Oak, Japanese | *Quercus grosseserrata* | Japan | 43-50 | Lighter than Austrian oak (light brown tinged with grey rather than red), not so pronounced "silver grain" and not so strong; very even textured; works easily to smooth finish. | Similar to Austrian oak but more suitable for interior work (such as panelling, flooring, furniture) than for external constructional work. |
| Oak, Silky | *Cardwellia sublimis* | Queensland, Australia | 38 | Pinkish brown, similar to American red oak; characteristic "silver grain" figure resembling true oak (hence the name); straight grain, coarse even texture; easily worked, moderately durable; stains and polishes well; does not respond to fuming. | Panelling, veneering, furniture and similar decorative work. |

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE II—*continued*

HARDWOODS—*continued*

| STANDARD NAME. | BOTANICAL NAME. | SOURCE. | WEIGHT (lb. per cub. ft.). | CHARACTERISTICS. | USES. |
|---|---|---|---|---|---|
| Oak, Tasmanian (Victorian oak, mountain ash) | *Eucalyptus obliqua, E. regnans, E. gigantea* | Tasmania Australia | 51 (*obliqua*) 41 (*regnans*) 45 (*gigantea*) | Light brown, resembling American or plain-sawn English oak (p. 22), but lacks the "silver grain" characteristic and is not durable when exposed. | Flooring, furniture. |
| Obeche . . . | *Triplochiton scleroxylon* | West Africa | 24 | White to pale straw; interlocked grain producing striped figure, coarse even texture; easily worked; not durable. | General joinery, plywood, blackboards. Substitute for canary whitewood (p. 24). |
| Olive, East African . | *Olea hochstetteri* | Kenya | 56 | Light brown with dark greyish brown markings; slightly interlocked grain, fine even texture; strong, moderately durable; difficult to work. | Flooring, panelling and similar decorative work. |
| Padauk, Andaman . . | *Pterocarpus dalbergioides* | Andaman Islands, India | 49 | Dark reddish brown; interlocked grain producing ribbon figure; difficult to work; strong, very hard, durable; takes high polish. | Superior joinery and decorative work such as panelling, fittings, bank counter tops, furniture. |
| Padauk, Burma . . | *Pterocarpus macrocarpus* | Burma | 54 | Golden brown; grain, etc., as above. | As above. |
| Pyinkado . . . | *Xylia dolabriformis* | Burma | 62 | Dull reddish brown; straight and interlocked grain; resinous; very difficult to work; exceedingly strong, hard and durable. | Heavy constructional and marine work; flooring. |
| Rosewood, Honduras . | *Dalbergia stevensonii* | British Honduras | 60 | Purplish brown with irregular black markings producing an attractive figure; straight and wavy grained; hard, dense, difficult to work; very durable; polishes well. | High-class decorative work such as panelling, veneering, furniture. |
| Rosewood, Indian (Bombay blackwood) | *Dalbergia latifolia* | India | 54 | Similar to Honduras rosewood; interlocked figure producing beautiful ribbon figure. | As above, including parquet flooring. |
| Sapele (sapele mahogany) | *Entandrophragma cylindricum*, etc. | East and West Africa | 40 | Dark reddish or purplish brown; interlocked and wavy grain producing attractive blister, roe, stripe and fiddle-back figure; cedar-like scent; very hard and strong; moderately durable; not easy to work; polishes well. Included amongst commercial mahoganies. | Superior decorative work as for panelling, interior fittings, furniture, veneering. |
| Satinwood, East Indian (flowered satinwood) | *Chloroxylon swietenia* | Ceylon, India | 62 | Golden yellow to dark brown heartwood, white to yellow sapwood; interlocked grain producing attractive ribbon and mottled figure; dense, hard, very durable; difficult to work; fine, even, lustrous texture; polishes well. | As above. |
| Satinwood, West Indian (Jamaica satinwood) | *Zanthoxylum flavum* | West Indies, Florida (U.S.A.) | 56 | Resembles East Indian satinwood, but is not so hard and is less durable. | As above. |
| Seraya, Red . . | *Shorea macroptera*, etc. | North Borneo | 36 | Similar to lauan (p. 21). | Substitutes for mahoganies (p. 21). Interior joinery, shopfitting, veneers, plywood. |
| Seraya, White . . | *Parashorea malaanonan*, etc. | | 35 | | |
| Sycamore (great maple, plane) | *Acer pseudoplatanus* | British Isles | 39 | White or yellowish white; distinct growth rings and rays; straight and wavy grain producing attractive rippled figure; fine, lustrous texture; strong, not durable; works fairly easily; stains and polishes well. | Superior decorative work, as for panelling, furniture, choice veneers, table tops, dairy appliances. Supplies are limited. |
| Teak . . . . | *Tectona grandis* | Burma, Java, Siam | 41 | Golden brown, occasionally with dark markings or flecks; ring porous; growth rings and rays indistinct; straight grained, not easily worked (saws, cutters, etc., being dulled); strong, hard, very durable; fire-resistant. | Superior general joinery and carpentry, marine work, veneers, plywood. |

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

TABLE II—*continued*

HARDWOODS—*continued*

| STANDARD NAME. | BOTANICAL NAME. | SOURCE. | WEIGHT (lb. per cub. ft.). | CHARACTERISTICS. | USES. |
|---|---|---|---|---|---|
| Teak, Rhodesian . . | *Baikiœa plurijuga* | Northern and Southern Rhodesia | 57 | Reddish brown, occasionally with irregular black markings or flecks ; straight or slightly interlocked grain ; difficult to work ; very hard, strong and durable. Not a true teak. | High-class flooring. |
| Walnut (English, European, Black Sea, French, Circassian and Italian walnut) | *Juglans regia* | Europe, including British Isles | 41 | Variable in colour, irregular dark veins on a greyish brown background producing beautiful figure ; finely figured burrs and crotches ; hard, tough, strong, moderately durable ; fine texture ; takes an excellent polish. | Superior decorative work, including panelling, furniture ; burrs and crotches highly valued for veneers ; gun and rifle stocks. |
| Walnut, African (Benin and Nigerian walnut) | *Lovoa klaineana* | West Africa | 35 | Yellowish brown background with dark markings (due to gum veins) ; interlocked grain producing ribbon or stripe figure. Not a true walnut. | Superior decorative work and joinery. |
| Walnut, American Black | *Juglans nigra* | U.S.A. | 44 | Similar to English walnut, but darker and more uniform in colour. | Similar to English walnut. Diminishing supplies and demands. |
| Walnut, Queensland (Australian walnut) | *Endiandra palmerstonii* | Queensland, Australia | 46 | Light or pinkish brown to dark brown, with varicoloured markings ; interlocked and wavy grain producing a broken striped figure ; difficult to work (dulls tools). | Superior decorative work such as panelling, veneers, furniture, plywood. |
| Whitewood, Canary (American whitewood) | *Liriodendron tulipifera* | U.S.A. | 32 | Yellowish brown with greenish tinge ; diffuse porous, pores just visible ; growth rings distinct, rays indistinct ; straight grained, easily worked ; stains and polishes well. | Joinery, plywood. High cost restricting its use, obeche (p. 23) being used as a substitute. |

NOTE.—*Some timbers are also known by those names appearing within the brackets in the first column.*

## PREPARATION OF TIMBER

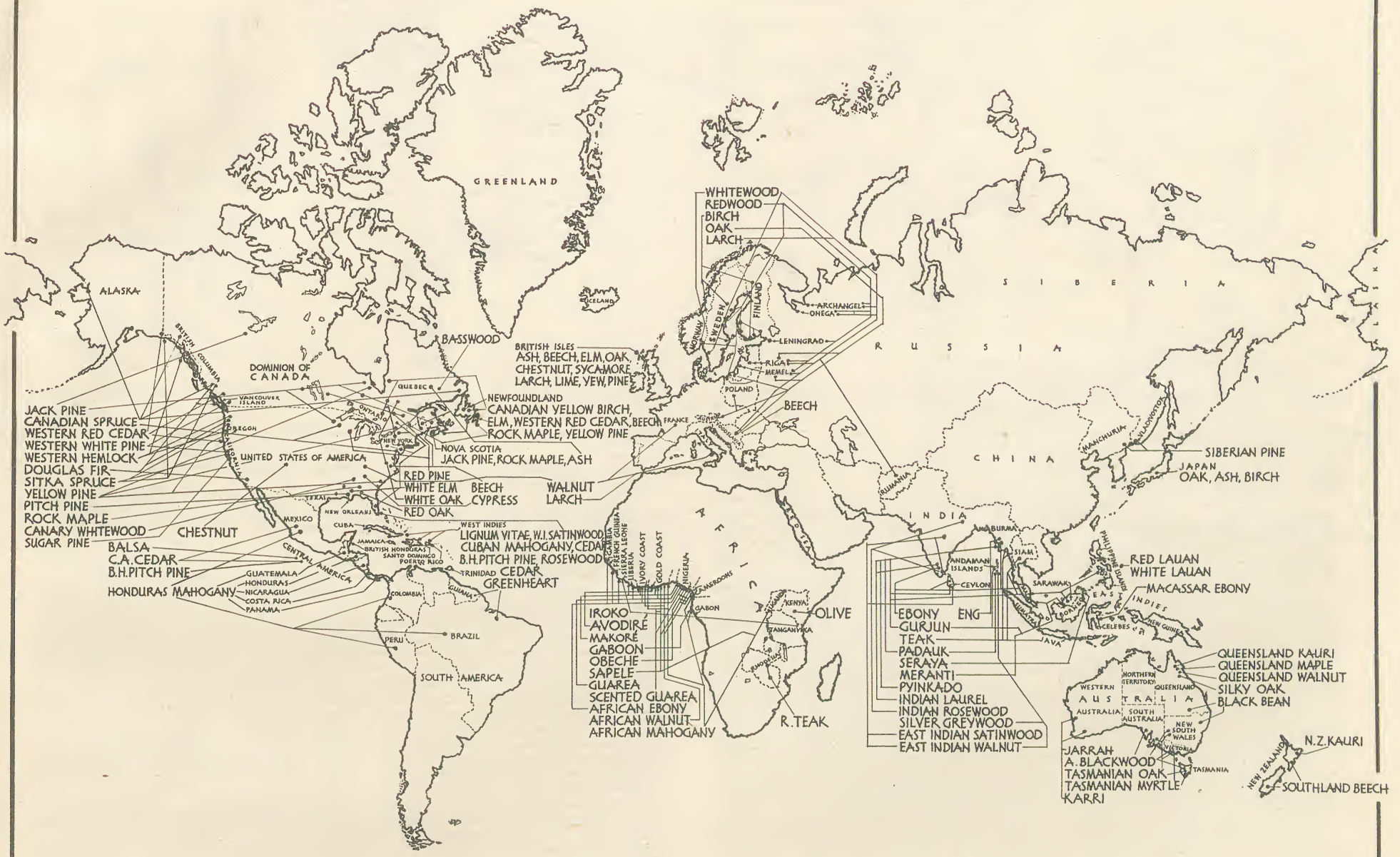
Hand tools used by the carpenter and joiner are described on pp. 126-130, Vol. I. The considerable use now made of woodworking machinery has revolutionized those sections of the building industry in which timber is employed. Machines have speeded up output and reduced costs, and comparatively little hand labour is needed in the well-equipped workshop, as practically all woodworking processes normally required can be done by machinery. Certain of the heavier machines used in the conversion of timber have been described on pp. 5 and 6. The following are some of the machines which are used in the preparation of timber : (1) Circular sawing machine, (2) band sawing machine, (3) planing and surfacing machine, (4) surface-planing and thicknessing machine, (5) panel planing and thicknessing machine, (6) moulding machine, (7) spindle moulder, (8) planing and matching machine, (9) mortising machine, (10) tenoning machine, (11) double-dimension saw bench, (12) dovetailing machine, (13) lathe, (14) mitreing machine, (15) sand-papering machine, (16) universal woodworker and (17) sharpening machines.

1. CIRCULAR SAWING MACHINE OR CIRCULAR SAW BENCH (see G, Fig. 5).—This, consists of a vertical circular saw, protected by a guard to which a riving knife is attached, and a metal guide or fence. The spindle of the saw is mounted on a frame having a flat metal table. The saw varies from 9 to 60-in. in diameter and the table or bench is from $2\frac{1}{2}$ to 8-ft. long and 2 to $3\frac{3}{4}$-ft. wide. The revolving saw runs in a slot in the table. The fence, which is parallel to the saw, can be readily adjusted, the distance between its face and the saw being regulated to the width to which the timber is to be sawn. Some machines have fixed tables, whilst others have " rising and falling " tables and fences which can be canted through 45°, the latter being useful for bevelling. This machine is extensively employed for general sawing purposes, such as sawing baulks into planks, deals, etc. (known as *deep-cutting*), or into smaller scantlings (called *flat-cutting*), ripping, edging and cross-cutting. Each piece of timber is pressed against the fence (unless it is to be cross-cut), which has been adjusted to the required distance from the saw, and fed towards the rotating saw ; the pressure is maintained as the timber slides forward on the table during the cutting operation. The riving knife, which is immediately behind the saw, widens the cut in the timber and thus prevents pressure on the saw.

*Circular saws* are made of crucible cast steel plates. The common form, shown at A and P, Fig. 6, and known as a *plate saw*, is a disc of uniform thickness or gauge throughout, the thickness depending upon the size of the saw and the character of the wood to be sawn ; thus, the normal thickness of a saw of 24-in. diameter is 12 B.W.G. (approx. $\frac{1}{10}$-in.) for hardwoods and 13 B.W.G. for softwoods, whilst the thickness of a 30-in. saw is 11 B.W.G. for hardwoods and 12 B.W.G. for softwoods. They are conveniently divided into *rip saws* (those which cut with the grain) and *cross-cut saws* (which cut across the grain). As the fibres of the wood are parallel to the plane of the saw during ripping and perpendicular during cross-cutting, and as timbers vary in hardness, it follows that the shape of the teeth differ in accordance with the work for which the saw is to be used.

Sketches of teeth of a rip saw are shown at B and C, Fig. 6, and those of a cross-cut saw are shown at D and E. The names of the various parts are indicated on the enlarged elevations G and M. The *hook* or *rake* is the inclination of the *front* or *face* of the tooth ; in all ripping saws the cutting *point* of a tooth is forward to form a *forward hook* (see G and M) ; the teeth of cross-cut saws have usually a *backward rake* (see E and D) and occasionally no

# MAP SHOWING THE DISTRIBUTION OF THE PRINCIPAL BUILDING TIMBERS




NOTE: THE TIMBERS INDICATED ARE SELECTED FROM THOSE USED IN THE BRITISH ISLES FOR BUILDING PURPOSES.

FIGURE 4

## WOODWORKING MACHINERY

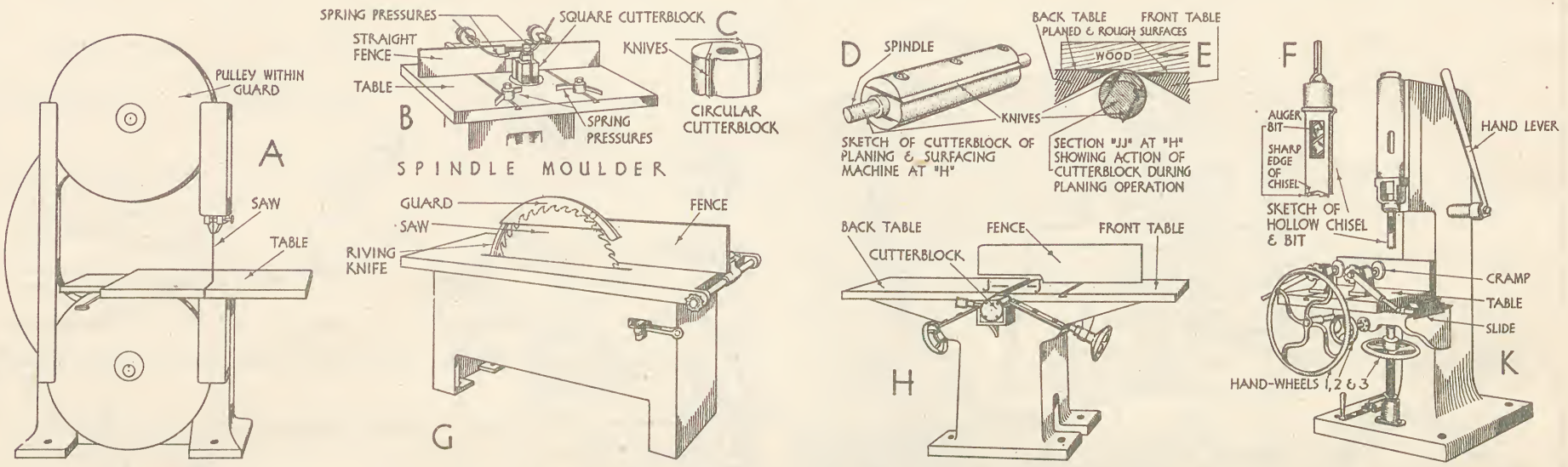



FIGURE 5

hook. The *gullet* must be sufficiently large and well rounded to remove the sawdust rapidly during the cutting operation.

*Set.*—The setting of the teeth of hand saws to produce the cut or *kerf* of greater width than the thickness of the blade is referred to on p. 127, Vol. I. A similar clearance or set must be given to the body of a circular saw so as to eliminate friction, otherwise the timber would bind on the saw, generating heat and causing the saw to wobble. This clearance must be equal on each side if " pulling " to one side is to be avoided. Teeth are either (*a*) *spring set* or (*b*) *swage set*.

(a) *Spring Set or Side Set.*—In this type the points of the teeth are bent over to the right and left alternately. Only the extreme points are sprung over, as shown at F and H, Fig. 6. The amount of set depends upon the nature of the timber. In general, hardwoods require less set than softwoods, and the set is increased when wood of a woolly and binding character is to be sawn. As a rule the set required for a 36-in. diameter saw is about $\frac{1}{32}$-in. bare for cutting hardwoods and $\frac{1}{16}$-in. full for sawing softwoods. The tool used for bending the points of the teeth is called a *saw set*. This is a small steel tool, having several notches of various widths on each of its two edges, and provided with either one or two handles. When setting, the notch in the tool corresponding to the thickness of the saw plate is fitted over the point of the tooth and bent over in the required direction as slight pressure is applied on the handle of the tool. Another tool, called a *set gauge*, is used to measure and ensure the uniform projection of the teeth on each side of the saw. This is a small piece of steel having a straight edge which is notched at the end by an amount equal to the required set. When applying the set gauge, its straight edge is held square along the centre-line of the saw, and the point of the tooth should just touch the notched top of the gauge ; any adjustment of the tooth is made by the saw set.

The top of each tooth of a rip saw is sharpened with a slight bevel, called the *top bevel* (see F and G) ; this enables the outer and higher extreme point to lead in the saw cut. The front of each rip-saw tooth has little or no bevel, but both the front and back of cross-cut teeth are bevelled on alternate sides.

Spring-set teeth are often used for ripping and cross-cutting. Setting of the teeth can be done by the automatic saw sharpening machine described on p. 30.

(b) *Swage Set.*—The point of each tooth when swage set is pressed out so that it slightly extends an equal distance on each side of the saw (see K and N, Fig. 6). Thus, each tooth clears both sides of the saw, whereas in spring set every other tooth clears one side and the alternate teeth the other. Two tools are used for swaging or spreading the teeth, *i.e.*, the *swage* and the *side dresser* or *swage shaper*. The former consists of a block of steel having a slot to admit the saw blade, and an internal anvil and eccentric die ; the top of the tooth is pressed against the anvil, a handle is turned causing the die to apply pressure on the face of the tooth as it spreads out the point. The side dresser ensures a uniform width across the points of the saw ; this steel tool has two metal dies between which the point of each tooth is squeezed, the finished width being determined by an adjustable steel plate which rests on top of the tooth.

Swage set is preferred for rip saws, log band saws, re-saws and frame saws. A faster feed can be employed when a saw is swage set and not spring set.

The above cross cut and rip saws are of uniform thickness. Another form of circular cross-cut saw, known as a *hollow-ground saw*, is of uniform thickness at the centre (for the diameter of the collar—see p. 27) and, after being reduced, gradually increases in thickness towards the rim (see Q, Fig. 6). It is used for accurate work. The teeth require no set.

The *ground-off saw* and the *swage saw* or *bevelled saw* are two other types of circular saw which are not of uniform thickness throughout. Both are thinner at the rim than at the centre, the ground-off saw (see R, Fig. 6) having a thin parallel rim of 1 to $1\frac{3}{4}$-in. width and increasing in thickness by a slight concave taper on one side only, and the

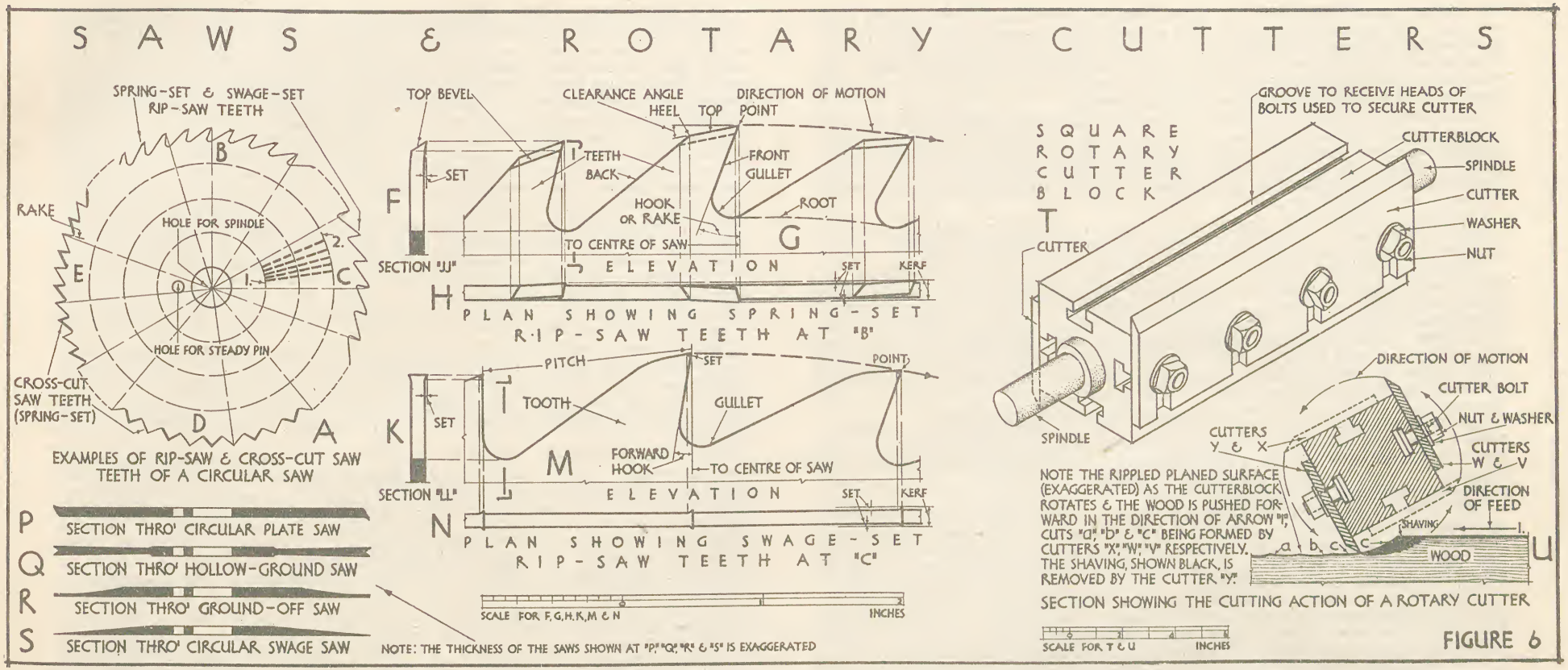



FIGURE 6

swage saw (see S) is tapered on one side from the rim towards the edge of the collar. They are either spring set or swage set. Both produce thin clean saw kerfs, and are used for cutting thin boards only, the ground-off saw being chiefly used for cutting boards from $1\frac{1}{8}$ to $\frac{3}{8}$-in. thick and the swage saw for sawing boards up to $\frac{3}{4}$-in. thick.

*Tensioning.*—A saw after continuous use becomes stretched at the rim ; if not attended to it will fail to cut true and will run noisily. Therefore, in order to obtain efficient performance, it is essential to examine the saw and recondition it when necessary. This correction is obtained by a process of hammering known as " tensioning." The process is usually confined to the middle half of the saw and the *radial hammering* method is one of several which produces satisfactory results. Thus, if concentric circles are chalked off as shown by thin broken lines at A, Fig. 6, light hammering (by a round-faced or *dog-head hammer*) is performed, working from the outside to the inside, *i.e.*, from " 2 " to " 1 " as indicated by the thick broken lines. The saw is hammered on an anvil, and both sides of the saw are dealt with in this manner. This expands the metal over this area and counteracts the expanding effect at the rim when the saw revolves at a high speed.

A saw to be tested for tension is laid horizontally on a table or anvil and is raised at one edge. A metal straight edge is placed on the saw, extending from the centre to the circumference. If correctly tensioned, the ends only of the straight edge should touch the saw, and there should be a space between with a maximum at the centre. The whole area is tested in this manner and the clearance between the saw and straight edge should be uniform. Absence or deficiency of tension is indicated when the surface of the saw between the ends of the straight edge touches, or almost touches the edge, and also if the saw shows " round " under the straight edge.

Improper treatment of the saw whilst in operation may produce bright or blue coloured bulges on the surface, known as *lumps* or *blisters*. The exact shape of these is determined by the straight edge and marked ; the saw is placed on the anvil and the lumps are removed by the gentle application of a round-faced or *cross-face hammer*.

A circular saw is fitted on the spindle of the machine between two collars (one being " fast " and the other " loose ") and secured by a nut ; a " steady pin " projects from the face of the fixed collar and engages in the small hole in the saw. The saw runs in a slot in the table (see p. 24). A *packing* must be placed in the slot on each side of the saw between it and the table. A good type of packing consists of a thin strip of wood round which spun yarn, afterwards oiled, is wound ; this is about 1-in. wide, and its length extends from the collar to just short of the base of the teeth. The packing must just be sufficiently tight for the purpose, excessive thickness being reduced by hammering on the wrapping. Correct packing prevents deflection of the saw and ensures steadiness.

*Speed.*—The speed of a circular saw depends upon its type, size and class of wood to be sawn. The most effective *rim speed* (that at the circumference of the saw) for general purposes is 10,000-ft. per min. The rim speed, divided by the circumference of the saw, gives the number of revolutions. Thus, for a 24-in. diameter saw the revolutions per minute are 1,590 ($10{,}000 \div \pi d$), and for a 36-in. saw, 1,060 revs. per min.

2. BAND SAWING MACHINE (see A, Fig. 5).—This is similar to, but much lighter than,

the vertical log band mill (p. 6) in that the band saw is strained over two pulleys placed one above the other. The diameter of the pulleys is 30, 36, 42 or 48-in., a useful size for general purposes being the 36-in. machine. The saw blade varies in width from ¼ to 1½-in. The timber is hand-fed on a 3-ft. square table which is about 3-ft. above the floor. This machine is used for shaping pieces by straight or circular cuts. The table may be canted and locked in position when required for bevel cutting.

PLANING AND MOULDING MACHINES.—There is a big similarity between these two classes of machines, as the function of both is to reduce each sawn piece of timber to accurate size and to produce a smooth and true finish to one or more surfaces. The planing machine shaves or planes *flat* surfaces, and, as implied, the moulding machine forms a *moulded* surface. Planing is achieved by steel knives or cutters. There are two kinds of cutters, *i.e.*, (*a*) rotary and (*b*) fixed.

(a) *Rotary Cutters.*—This type consists of knives bolted in a steel block, called a *cutterblock*, fixed on a rotating spindle, the latter being mounted on bearings. Cutterblocks are either square or circular in section.

A *square cutterblock* is shown at T, Fig. 6, and has either four knives or cutters, one bolted on each face, or two knives mounted on a pair of opposite faces. A square cutterblock, with the knives omitted, is shown in position at B, Fig. 5. A diagrammatic view showing the cutting action of rotary cutters (in this case fixed above the timber) is shown at U, Fig. 6. As the cutterblock rotates at a high speed, the projecting edges of the knives cut shavings or chips from the advancing wood. The portion of wood, shown black, indicates the chip which would be removed by knife "*Y*" as it rotates. It will be seen that the planed surface is composed of waves or ripples; the quality of the surface is improved as the number of knives or the speed of the spindle is increased.

*Circular cutterblocks* are shown at C, D and E, Fig. 5; each carries two (as shown) or more knives. The cutterblocks are placed horizontally in some machines (see E and H), vertically in others (see B), and certain machines, such as moulding machines (see next column), have both horizontal and vertical cutterblocks. The cutting action of the knives of a circular cutterblock is shown at E.

(b) *Fixed Knives or Cutters.*—These are fixed on certain machines, *i.e.*, the planing and matching machine (p. 29), at the bottom and sides. They shave the wood and produce a superior finish to the surfaces. The result is similar to that produced by the hand plane (see J, Fig. 67, Vol. I), but as the knives are fixed, the timber must be pressed against them as it is guided rapidly past. The speedier the feed the better the finish.

Most planing machines are designed to perform additional labours, including moulding, thicknessing, grooving, beading, chamfering, etc. (see below). Whilst a combined planing and moulding machine is an advantage in a workshop having a small mixed output, it is desirable to have an independent moulding machine when the output is large. Three reasons for this are: (*a*) The fast feed speed required on a planing machine is not desirable on a moulder when the mouldings are required to have fine surfaces; (*b*) a common cutterblock cannot be conveniently used for both purposes; and (*c*) the feed rollers best for flat planing are not of the type most desirable for working mouldings.

3. PLANING AND SURFACING OR PLANING AND JOINTING MACHINE (see H, Fig. 5).—This consists of back and front tables, a cutterblock and an adjustable fence. The overall length of the tables varies from 6 to 10-ft., the larger type of machine being capable of planing timber of a maximum width of 30-in. An enlargement of the cutterblock, containing two knives, is shown at D and a section is shown at E. The tables can be adjusted by the hand-wheels to enable the back table to support the timber and the front table to regulate the depth of the cut. The section E shows a piece of timber partially planed as the cutterblock rotates in the direction of the arrow at a speed of 4,000 revs. per min. The cutterblock has a guard (not shown) to protect the operator. The fence can be canted for chamfering and bevelling. This simple hand-fed machine is used for planing, surfacing, jointing, bevelling, rebating and chamfering. If a face and edge of a piece of timber are to be planed, it is first placed flat and pressed against the table (or held down by two springs similar to those shown at B) and passed over the rotating cutter; the piece is then edged in a similar manner with the dressed face against the fence.

This machine can also be obtained with a mechanical feed. This feed unit is superimposed over the table and consists of two endless travelling chains having projecting steel points. These points grip the timber and guide it forward over the cutterblock. The maximum rate of feed is 55-lin. ft. per min.

4. SURFACE-PLANING AND THICKNESSING MACHINE.—The object of this machine is to reduce the timber to a parallel thickness in addition to planing its surfaces. It resembles machine H with the addition of a second table, situated below the back and front tables. The bottom table can be raised or lowered as required, the vertical distance between the upper surface of the bottom table and the edge of the knife in the cutterblock (when immediately below its centre) being equal to the required finished thickness of the timber. If a piece of timber is to be thicknessed and planed on all four sides, an edge and one face are first planed on the top table, as explained in the preceding column, after which the piece is placed with the dressed face resting on the bottom table, and the upper face is dressed by the cutterblock as the timber is fed mechanically by the rollers. The second edge is finally dressed in a similar manner, a process known as *widthing*. The maximum size of timber which can be dealt with is 30-in. by 9-in. and the maximum rate of feed is 46-lin. ft. per min.

5. PANEL PLANING AND THICKNESSING MACHINE.—One form of this powerful machine consists of a table, a cutterblock having three, four or six knives, a mechanical feed of rollers, pressure bars to hold the timber firmly down on the table and a *chipbreaker* to break up and discharge the chippings. One of the heavier types is capable of dealing with timber of 36-in. maximum width and up to 9-in. thick. The cutterblock, being above the table, planes the upper face and reduces the thickness of the timber. The maximum rate of feed is 90-lin. ft. per min.

Another form of this machine is provided with two cutterblocks, a bottom one (at table level) near the front, and a top cutterblock near the back. Two surfaces can be dealt with at the same time, and thus the machine acts as a double surfacer. In addition, two side vertical cutterblocks can be fitted near the back end of the machine; it thus acts as a *four-cutter planing and thicknessing machine* and is capable of planing all four sides at once.

6. MOULDING MACHINE.—There are several types of machines used for forming moulded surfaces. The cutterblocks and cutterheads are provided with cutters shaped according to the moulded section of timber to be produced. A moulding of complicated design will require more than one cutter to form it. Moulding machines may have either four, five or six rotary cutterblocks. Thus, a *six-cutter* has the following at intervals, commencing near the feed end: A bottom cutterblock, two side cutterblocks (one at each side), a top cutterblock, a second top cutterblock or *profile head*, and a second bottom or end cutterblock or *beading head* near the back end; this is suitable for large mouldings. A *five-cutter* is similar but without either one of the bottom or top cutterblocks; the side cutterblocks may either precede or be between the two top cutterblocks. A *four-cutter* has bottom and top cutterblocks and two side cutterblocks.

The feed is by means of two pairs of rollers (the first being fluted) through which the timber is guided and propelled; the rollers are driven by gearing controlled by a three, four, six or nine speed gearbox, depending upon the type of machine. The timber is pressed against the table and/or fence by *pressures* such as smooth rollers or pads over or adjacent to the various cutters. A chipbreaker is provided. The maximum size of timber which can be dealt with varies; thus, one type of six-cutter can deal with sections up to 15-in. by 6-in., whilst another is designed to take a maximum size of 12-in. by 4-in.; the capacity of some four-cutters is limited to 4-in. by 2-in. stuff.

There is a big variation in the feed-speeds; thus, one six-cutter machine has a range of speeds up to 160-lin. ft. per min., whilst some four-cutters have a maximum feed-speed of 45-lin. ft. per min. only. The speed depends upon many factors, such as the size, kind and quality of the timber, number of cutters, quality of finish required, power available, etc. As mouldings of high finish are usually required, it is customary to feed the machines at much lower speeds than the maximum, otherwise ridges or "ripple marks" (see U, Fig. 6) will be more pronounced.

The latest type of "high-speed" planing and moulding machine which can be built up with either four, five or six rotary cutterblocks in addition to fixed knives, has six rates of speed varying from 25 to 200-lin. ft. per min. The fixed knives, which produce a high quality finish, consist of two bottom knives and two side knives, and are situated between the first cutterblock and the side cutterblocks. It is necessary to use an *automatic feeding table* in order to obtain the maximum output from this high-speed machine. This may be 20-ft. long by 2 to 2½-ft. wide, and has six grooved bottom rollers at intervals along its length, with two top rollers at the planing machine end; it has a fence along one side and a sloping board along the other, on to which the pieces of timber are dropped

and from which they slide on to the rollers to be delivered to the moulding machine. The feed table is connected to the feed mechanism of the moulding machine and its speed is in excess of that of the machine.

7. Spindle Moulder or Vertical Spindle Moulding Machine (see B, Fig. 5).—This is a useful machine for forming mouldings on straight, curved or irregularly shaped lengths of timber; it is also used for planing, edging, recessing, tonguing, grooving, tenoning, dovetailing and jointing. The cutterblock may be circular, as shown at C, or square, as shown at B. It is provided with a pair of straight fences and a pair of *ring* or circular fences, all of which can be moved and fixed in position on the table to suit the timber. Two adjustable spring pressures are fixed to the straight fences for holding the timber to the table and against the fences. The spindle speeds are usually 3,000, 4,500 and 6,000 revs. per min. It can rotate in either direction to suit the grain of the wood. A guard, not shown, is fitted over the cutter spindle to protect the operator. This machine is hand-fed and is known as a *single-spindle moulder*. Another type has two cutter-spindles and is hence called a *double-spindle moulder*. Both types can be mechanically fed when large outputs are required, the maximum speed-rate being 45-lin. ft. per min.

8. Planing and Matching Machine.—This very powerful machine, which is at least 20-ft. long and 4½-ft. wide, is designed to produce large and speedy outputs of accurately machined floor boarding, match-boarding, skirtings, etc. The maximum output from the latest type can exceed 350-lin. ft. of tongued and grooved floor boarding per minute, and the maximum size of timber which the largest can deal with is 15-in. by 6-in. It is provided with either four, five or six rotary cutterblocks. It has, in addition, either two, three or four horizontal fixed knives in a box immediately after the first bottom cutterblock for producing a first-class finish to the face; side fixed knives may also be fixed next to the side cutterheads. They are positioned as described for moulding machines (p. 28).

The cutterblocks fixed on the side vertical spindles which form the tongue and groove on the edges of floor and match-boarding are called the *tonguing head* and *grooving head* respectively. The tonguing head has either six or eight cutters; each alternate cutter forms the edge and upper portion of the tongue during rotation, and the remaining cutters form its lower portion. The grooving head has either eight (four for edging and four for grooving) or twelve (six edging and six grooving) cutters; the straight edging cutters plane the edge of the boarding and alternate with the projecting grooving cutters or *bits*.

For tongued and grooved and single or double vee-jointed match-boarding (see L and M, Fig. 44, Vol. I) the cutters of both the tonguing and grooving heads are shaped to form the necessary chamfers. The bead at the tongued edge of the tongued and grooved and single beaded matching (see N, Fig. 44, Vol. I) is formed by the second horizontal bottom cutterblock or beading head of the six-cutter machine; if the matching is double beaded (see O) the second bead is shaped by the second top cutterblock. Other labours on the edges, such as are required for the boards shown at Q, V and W, Fig. 34, Vol. I, are formed by suitably shaped cutters in the side cutterblocks.

One type of machine is fitted with eight feed rolls (18-in. in diameter), two pairs immediately before the first cutterblock and two pairs before the side cutterblocks. It is provided with suitable pressures. A shaving breaker is mounted below the fixed knives to reduce the long shaving to small particles. An automatic feeding table, described on p. 28, must be provided.

The rates of feed vary. Thus, one machine has twelve distinct rates of feed varying from 22 to 350-lin. ft. per min. Another has nine rates varying from 68 to 450-lin. ft. per min. Those used for production work only have minimum and maximum speeds of 200 and 520-lin. ft. per min.

A four-cutter planing and matching machine will be suitable for flooring, plain matching and simple moulded skirtings. Thus, for tongued and grooved boarding, the sawn boards are successively (1) planed on the lower face by the bottom cutterblock, (2) given a high finish by the fixed blades (although these are not always provided), (3) planed and grooved on one edge by the grooving head, and tongued and reduced to the correct width by the tonguing head, and (4) finally reduced to the required thickness by the top cutterblock. Five and six cutter machines are necessary for beaded matching, more elaborate moulded skirtings, etc.

9. Mortising Machine (see K, Fig. 5).—This is used for mortising framing of doors, windows, etc. The two cutting tools chiefly used are the *hollow chisel* and the *chain cutter*.

The hollow chisel mortiser, as shown at F, Fig. 5, consists of a chisel in the form of a tube, square in section, and an auger bit which revolves within the chisel. The normal size of the chisel is up to 1-in. square (1½ and 2-in. square chisels are used in the heavier machines), and its lower end has a fine cutting edge. The chisel is attached to a spindle and works with an up-and-down movement, and the stroke can be varied to give any depth of mortise down to 8-in.

A chain cutter is an endless chain with links having cutting teeth on the outside. The chain travels vertically at a high speed over a top sprocket (cogged) wheel fixed to the spindle and a bottom guide wheel forming the lower end of a tension bar. The width of the chain varies from ¼ to 1½-in. and is capable of forming a mortise of 6-in. maximum depth.

The movement of the chisel is controlled by the hand lever. The timber is fixed to the table by one or two adjustable cramps. The table can be raised and lowered by a central screw when operated by handwheel "3"; it can be moved either backwards or forwards by a screw operated by handwheel "2," and longitudinally over the slide by operating handwheel "1."

Handwheels "2" and "3" are manipulated until the table is correctly positioned, *i.e.*, the position of the mortise marked on the cramped timber is brought immediately under the chisel, which has been lowered until it almost touches the wood. Once the table has been set it is not necessary to alter its transverse position and height, provided all the timber is of the same scantling and the size and relative position of the mortises are common.

Mortising is performed by the simplest type of hand-lever machines by lowering the lever; this drives the chisel through the wood. The lever is raised; handwheel "1" is manipulated by the free hand to give the necessary short lateral movement of timber and the lever is again lowered. This is repeated until the mortise has been completed. If the machine is of the automatic type, the reciprocal feed motion of the chisel is controlled by the hand lever having automatic knocking-off and adjustable stops; mortises of uniform length are thus formed rapidly. In one type of automatic machine the feed of the chisel is operated by a foot lever, and the movement of the chisel continues automatically until the foot is released from the pedal of the lever.

In some machines the head carrying the hollow chisel can be quickly substituted for the chain cutter head. The mortising machine shown at K may be fitted with a chain cutter attachment in addition to the hollow chisel. Alternatively, a *boring* attachment, consisting of a spindle carrying a rotating auger, can be fitted. A boring machine is a form of mortiser, it being used to form circular holes for dowelling, etc. The auger, like the hollow chisel, has a vertical movement and is controlled by a hand lever. Some multiple-boring machines carry four or more spindles which operate simultaneously by a hand lever or foot treadle. A boring machine may also be of the horizontal type, the auger spindle being placed at the side of the table; this is a useful machine for recessing and slot mortising, for which purpose the rise and fall tables, fitted with a fence, can be moved horizontally.

Another form of vertical boring machine is known as a *router* or *recessing machine* or *overhead spindle moulder*. This consists of a bench, a vertical cutter spindle similar to that shown at B (see preceding column) and another cutter spindle or boring tool mounted on an adjustable horizontal arm overhanging the table. The overhead cutter spindle is used for housing, recessing and trenching, as required for stair strings (to accommodate the ends of treads and risers, see pp. 84 and 87), shelving, recessed panels, etc.

10. Tenoning Machine.—The single and double tenoning of members of framing is performed by a machine which has two horizontal rotary cutterblocks, two vertical rotary scribing cutterblocks, a cross-cut saw and a table which travels on rollers. The two tenoning cutterblocks, one below the other, are at right angles to the travel of the table and carry two or four knives each; they can be adjusted both vertically and horizontally to suit the required thickness and length of the tenons. A cutter is fitted to the end of each cutterblock to sever the fibres across the grain and form clean cuts at the shoulders. The two vertical cutterblocks are adjustable for both top and bottom scribing. The cross-cut saw is adjustable and cuts the end of the timber prior to or after being tenoned and scribed. The sawing, tenoning and scribing are done in sequence at each

travel of the table, the scribing being the last operation as a rule. An adjustable *drunken saw* (so called because it appears to wobble when rotating) is used for double tenoning; this is attached to the bottom scribing spindle and replaces the bottom scribing block.

11. Double-dimension Saw Bench.—This is used for various classes of work (including ripping, cross-cutting, mitreing, grooving, rebating, bevelling and cutting compound angles) requiring accuracy in sawing to dimensions. The 44-in. by 40-in. table can be canted to 45°. A revolving frame carries two saws (usually a rip saw and a hollow ground cross-cut saw); that required for use is raised to the required height by turning a wheel; this operation lowers the other saw. The main fence can be accurately adjusted in any position and can be canted to 45° or swivelled to 30°. The front portion of the table can be moved laterally as required for cross-cutting, etc., and carries a mitreing and cross-cutting fence which is set to the required angle on reference to a graduated arc marked on the table or fence.

A *single-dimension saw bench* is similar to the above, but carries only one saw. This saw can be interchanged.

12. Dovetailing Machine.—Dovetailing of timber for drawers and similar work is performed by an automatic single spindle dovetailing machine consisting of a vertical or horizontal rotary cutting spindle, mounted on a slide, and a travelling table to which the timber is cramped. The movement of the table conforms with the reciprocating motion of the spindle as the latter enters and leaves the wood to form dovetails at the required spacing. One type of multiple spindle dovetailing machine for repetition work has a table (which accommodates two boards to be jointed at right angles to each other) fitted with an automatic mechanism for spacing the dovetails at the required pitch, and a complete dovetail joint is formed as the table moves past a series of cutters.

13. Lathe.—This is used for wood turning, examples being turned balusters, moulded newel caps and drops, legs of furniture, etc. The essential components are a fast headstock and a loose tailstock. These may be fixed on a wood bench or on a metal bed supported by legs. The headstock, usually fixed on the left-hand side, carries a short horizontal revolving spindle having a forked chuck to grip the timber and a three or four speed pulley. The tailstock is at the opposite end of the bench or bed and has a sliding horizontal spindle (carrying a tail centre which slightly penetrates and supports the end of the timber), operated by a handwheel; it can be moved and locked in any position along the bench.

The piece of wood to be turned is fixed horizontally between the stocks. The shaping of the wood is performed by a chisel or gouge of suitable shape which is fitted in a tool-holder and held against the wood as it revolves at a high speed; the cutting tool is held stationary or traverses the length of the timber as required during the shaving process. The tool, fixed in a holder and provided with an adjustable slide, may be used for turning long pieces; this is fitted to a sliding carriage which traverses the length of the bed.

For hand turning the tool is held and manipulated by hand, supported by a rest, various sizes and shapes of chisels and gouges being used in the process.

14. Mitreing Machine.—This machine, used for cutting mitres and squaring edges of timbers, is not power driven. It consists of a pedestal which supports a table and a knife which is operated by a hand lever. The timber is placed on the table, with one edge against a pivoting fence which has been adjusted to the required angle according to a graduated arc marked on the table, and the edge is cut by the knife on a downward stroke of the lever.

15. Sand-papering Machine or Sander.—Planed surfaces, especially if they have been prepared by rotary cutters, are uneven due to the presence of a series of ridges (see U, Fig. 6, and p. 28). In order to eliminate these ripples and give a smooth finish it is necessary to apply an abrasive paper (glass or sand-paper) to the surfaces. The hand application of this abrasive is referred to on p. 129, Vol. I. This slow and tedious process is gradually being superseded by the machine. There are three classes of sanders, *i.e.*, (*a*) drum, (*b*) belt and (*c*) disc.

(a) *Drum or Cylinder Sanders.*—One type, suitable for large outputs, consists of three horizontal drums which have a combined rotary and oscillating motion. Sand-paper is fixed to each drum, coarse grade paper being used to cover the first drum, medium grade the second and fine grade the third. These drums are superimposed over the feed mechanism, which may consist of a travelling endless belt or eight rollers. The timber is placed on the belt or feed rollers and suitable pressure bars or rollers ensure that it comes into intimate contact with the abrasive. The minimum rate of feed is 27-lin. ft. per min. One or more hoods are fitted over the drums and are connected by a pipe to an exhaust fan which extracts the dust from the machine.

A smaller machine is provided with either one or two drums.

(b) *Belt Sander.*—This comprises a travelling table, 8-ft. long and a 6 or 8-in. wide endless belt above, which passes over two pulleys and travels the full length of the table. The timber is placed on the table, and the belt, with abrasive paper attached, is pressed down for close contact by means of a pad. This machine is suitable for medium outputs.

A smaller machine consists of a 7-ft. by 2-ft. table with two vertical rollers near the ends, on which an 8-in. high belt travels. The timber is laid on the table and pressed against the belt by hand.

(c) *Disc Sander.*—One type consists of a pillar which supports a short revolving spindle at each end of which is a disc which varies from 20 to 36-in. in diameter. A small table, which can be canted, is fixed opposite to each disc. Abrasive paper is fixed to the outer face of each disc and the work is held against it during rotation.

A combined machine, known as a *disc and bobbin sander*, carries a disc with a table, as described above, and a vertical spindle called a bobbin. The latter operates in the centre of a table and has a vertical reciprocating and rotary motion. Both tables can be canted. The bobbin, which is covered with abrasive paper, is useful for curved work.

16. Universal Woodworker or General Joiner.—This is a general utility machine capable of satisfying the requirements of smaller establishments where different classes of work are dealt with and the output is insufficient to justify the provision of separate machinery.

One type consists of two sections. The front half comprises a horizontal rotary cutter-block, front and back tables and adjustable fence (somewhat similar to those shown at H, Fig. 5) for planing, surfacing, chamfering and jointing timber up to 12-in. wide. In addition, a vertical rotary cutter spindle arranged to rise and fall as required, is fitted in the middle of the front table and thus resembles B, Fig. 5; this is used for moulding circular and irregularly shaped pieces of timber up to 3½-in. thick. A further addition consists of a small rise and fall table in front of this half-section for hollow chisel mortising, boring and slot mortising; the chisel is fixed horizontally to the end of the horizontal cutter-block and overhangs the small table; the timber is fixed by a vertical cramp to the table, which can be moved longitudinally and transversely; the chisel is replaced by either the boring bit or slot mortising auger as required.

The back half of the machine consists of a rise and fall table, fence and a spindle to which is attached either a circular saw or a horizontal rotary cutterblock. The maximum size of saw is 24-in. diameter and will saw up to 9-in. deep; cross-cutting, mitreing and dimension sawing may be performed, as a steel plate to carry the timber and adjustable fence can be fitted to slide in a groove along the edge of the table. When required for tonguing, grooving, thicknessing and moulding, the saw is replaced by a horizontal cutterblock (5-in. long) carrying suitable knives. The table is lowered to bring it to the desired level below the cutterblock when the timber is to be moulded and thicknessed; the timber is first surfaced on one side and edge, and then thicknessed or moulded on the upper and opposite side; a power feed apparatus and pressures are provided for this purpose. The cutterblock is replaced by a suitable tenoning cutterblock for forming tenons, the maximum length of which is 5-in.; the timber is fixed transversely by a cramp to a plate and passed horizontally under the rotary cutter to form the upper portion of the tenon; the table, with plate and timber still attached, is then raised to the required height above the cutter over which the timber is passed to cut the opposite side of the tenon. Tonguing and grooving are performed when the cutterblock, with suitable cutters attached, is rotated against the timber, which is fixed to the table at a suitable height. For sand-papering, the cutterblock is replaced on the spindle by a small drum covered with sand-paper, and the operation is performed with the table adjusted at a suitable height.

17. Sharpening Machines.—There are many machines for conditioning saws, cutters, etc. These include—

*Automatic Saw Sharpening Machine.*—This is used for sharpening circular saws, the sharpening and gulleting (re-cutting the gullets to the correct shape, see G, Fig. 6) being done by a grinding machine which automatically grinds the whole profile of each tooth at one operation. The teeth can be ground square across or at any desired bevel. The grinding wheel, 8 or 12-in. in diameter, is fitted to a spindle which is provided with

a rise and fall movement and may be canted to suit the hook or rake (see A, G and M, Fig. 6) of the saw teeth. The shape of the teeth is governed by a cam operating the rise and fall of the grinding wheel. Cams are varied in their shape to suit different sizes of teeth and are easily interchanged. The saw is fed forward under the grinding wheel by a feed pawl or finger which engages against the face of the tooth being ground. The stroke of the pawl is adjustable to suit different pitches of teeth and positioning of the face of the tooth under the grinding wheel. The saw is mounted on a spindle fitted with a self-centering cone to suit the variation in diameter of the spindle hole in the centre of the saw. This spindle is adjustable both vertically (to suit the diameter of the saw) and horizontally, according to the varying rakes of saw teeth. The rate of feed is from 15 to 30 teeth per minute, according to the pitch of the teeth.

A similar machine is used for sharpening band saws. The saw during the grinding operation is stretched horizontally and passes round two pulleys as it automatically progresses forward to bring each tooth (or alternate teeth) under the frame holding the grinding wheel.

*Automatic Cutter Grinder.*—This is used for grinding and shaping cutterblock and planing knives. A knife is fixed horizontally to a travelling table which traverses to and fro under a rotary emery wheel which grinds the knife to the required bevel. In another type of machine the knives are not removed from the block, the spindle of which is supported at each end of a table which travels longitudinally during the grinding operation.

*Mortise Chain Cutter and Hollow Chisel Grinder.*—This is a small machine for conditioning the two cutting tools named. It is fixed to and driven by the mortising machine. The chain cutter is passed on to a sprocket mounted on a horizontal slide along which it passes to and fro under a specially shaped rotary emery wheel as the cutting teeth are ground. The machine also carries a cone emery wheel for sharpening hollow chisels.

*Grindstone.*—This is a cylindrical disc, 3 to 4-ft. in diameter and 6-in. thick, of Derbyshire grit or similar hard natural stone which is mounted on a spindle that is rotated during the grinding operation. A finer stone disc, which gives a keener edge, may also be mounted on the spindle in addition to the coarse disc. These rotate in troughs which contain water when wet grinding is required to prevent overheating. This machine is useful for general grinding, especially large hand tools.

A suitable machine for grinding smaller hand-cutting tools, such as chisels, gouges and planing irons, consists of a frame supporting a rotary spindle which carries four or six emery or sandstone (or both) discs which are 12-in. in diameter and of varying thickness. A water tap is fixed above each disc and a trough is provided below.

## FLOORS

Single floors are detailed in Vol. I, pp. 59-68. The other two types of boarded and joisted floors there referred to, *i.e.*, double and framed floors, will now be described.

Attention is drawn to the fire-resisting types of contemporary construction in which reinforced concrete floors (see Fig. 9 and B, Fig. 10) and hollow block or beam floors (see C, Fig. 10) are extensively employed and in which the minimum amount of timber is used.

DOUBLE FLOORS.—It is usual to limit the clear span of softwood bridging joists to 16-ft.[1] and therefore when the width of a room exceeds this figure one or more relatively large members, called *binders*, are introduced to act as intermediate supports for the bridging joists. Economy in material thus results, and the bridging joists, being much reduced in size, are more convenient to handle.

[1] This depends upon the grade of timber used and the superimposed load to be carried (see p. 32). Thus, if graded timber ($f$=1,200-lb. per sq. in.) is used and the superimposed load is 90-lb. per sq. ft., 11-in. by 3-in. joists are necessary for a span of 16-ft. Therefore this span is reduced if this load is exceeded in order that joists of stock size may be used.

These binders are spaced at from 6 to 10-ft. centres and are placed across the shortest span in order that their dimensions may be kept down to a minimum. Mild steel has largely superseded timber as a material for binders (see below) and flitched beams,[1] formerly used for long binders supporting heavy loads, are now at least obsolescent.

Plan, sections and details of a double floor are shown at A, B, C, D, E, F, G and H, Fig. 7. The plan at A shows the floor divided into three bays by the provision of two binders. Wood binders are still occasionally used, and they have therefore been detailed here (see below). With a view to reducing the over-all depth of the floor to a minimum and effecting an economy in the brickwork (to the extent of one or more courses), the bridging joists are cogged to the binders (see E, F and H). The depth of the sinking should not exceed two-thirds the depth of the bridging joists and their bearing need not exceed 1-in.; whilst such sinkings do not much reduce the strength of the binders, provided the workmanship is sound and the joists are a tight fit, the cutting and notching of bearing timbers should be restricted as much as possible. The binders are shown supported on stone pads. The latter provide sound bearings and effectively transmit the loads to the brickwork below; 3-in. thick stone lintels are also sometimes built-in above the ends of the binders. The necessary circulation of air round the ends of the binders is assured if pockets are provided, as shown at F and H.

Solid strutting of the bridging joists is sometimes resorted to, as shown at A and B, but this can safely be dispensed with (see p. 68, Vol. I), especially when the joists are cogged to the binders.

If the ceiling of the room is required to be flush with the soffit of the binders, the necessary construction is as shown. Small fillets, not more than 2-in. by 1-in., are securely nailed to the sides of the binders (see E, F and H) and plugged to the walls (see D and G). As shown, the ends of the 4-in. by 2-in. ceiling joists are notched to these fillets and nailed; plasterers' laths, spaced at "finger-distance" (about ⅜-in.) apart, are nailed to the ceiling joists (see G).[2] Short pieces of thick laths, called *counter-laths*, are nailed at 15-in. centres to the soffit of the binders (see E, H and S); such provision should be made when timbers exceed 3-in. in width and so afford a proper key for the plaster (see A, Fig. 8, which shows the plaster that has been pressed through the spaces between the laths). Several alternative details, showing the ceiling attached direct to the bridging joists, appear in Fig. 8 (see pp. 35 and 36).

The size of the wood binders shown is much in excess of the normal stock sizes. The difficulty which may be experienced in obtaining sound timber of large size is one of the reasons why, as stated above, steel has largely supplanted wood as a material for floor members such as binders. A detail incorporating

[1] A flitched beam consists of two wood joists (as shown at L, Fig. 8), with a wrought iron or steel plate between, all bolted together.

[2] As the subject of plastering is usually taken in the third year of a course, it is described in Vol. IV.

a rolled mild steel beam as a binder in lieu of a wood binder is shown at M, Fig. 7. Mild steel is much stronger than timber (the safe strength in compression and tension of mild steel is 18,000-lb. per sq. in. and that of a good graded softwood may not exceed 1,200-lb. per sq. in.) and therefore the size of the steel beam is less than that of a wood binder; the 9-in. by 4-in. by 21-lb. steel beam shown at M will support the same load as the 15-in. by 7-in. timber binder (compare M with E). One result of this reduction in size is the corresponding decrease in the amount of walling, equivalent in this case to approximately two courses of brickwork.

Second year students attending a complete course of instruction which includes the subject of Building Science in addition to Building Construction, will probably be taught to design simple rectangular beams, but the determination of sizes of rolled steel beams is usually deferred to a later stage. The following examples are therefore stated briefly and are included for reference purposes only.

DETERMINATION OF SIZES OF BRIDGING JOISTS AND BINDERS.—The Timber Bye-laws of the London County Council apply to two classes of timber, *i.e.*, "non-graded" and "grade 1,200-lb. $f$"; $f$ is the permissible working stress. The permissible maximum compression and tension stresses due to bending (to which joists and binders are subjected) are therein stated to be 800 and 1,200-lb. per sq. in. for non-graded and graded timbers respectively. The sizes of wood joists and binders can be obtained by reference to tables. Thus, assuming the floor illustrated at A, Fig. 7, is that of a residential building, the sizes of the bridging joists which are spaced at 15½-in. centres with an effective span (distance between bearings) of 9-ft. are computed to be 6·4-in. by 2-in. if of non-graded timber, and 5·4-in. by 2-in. if of graded timber. Reference to the same tables shows that the sizes of the binders, which have an effective span of 18-ft. and are spaced at 9-ft. centres, are 15-in. by 9·4-in. if of non-graded timber, and 15-in. by 6-in. if the wood is of the graded class.

The size of the bridging joists is determined by calculation as follows: (1) The total weight (W) that one of the joists supports is obtained; this equals the decided live or superimposed load [1] plus the dead weight,[2] multiplied by the area of the floor supported by the member. (2) The bending moment (M) is found; this equals the moment of resistance (MR), and the latter equals the product of the modulus of section (Z) and the permissible stress ($f$). (3) Either the breadth ($b$) or depth ($d$) of the joist is assumed and its second dimension then obtained. The size of the binders is ascertained in a similar manner.

Applying this to the floor shown at A, Fig. 7:—

BRIDGING JOIST A′.

1. *Weight.*—Assume the superimposed load is 50-lb. per sq. ft. The dead weight of the timber can be obtained from Tables I and II, pp. 17-24); the general figure taken for softwoods is 30-lb. per cub. ft. (41-lb. for pitch pine) and 45-lb. per cub. ft. for hardwoods. If 1⅛-in. softwood boards are used, their weight $=\frac{9}{8}\times\frac{1}{12}\times 30\text{-lb.}=3\text{-lb.}$ (approx.) per sq. ft. The bridging joists are spaced at 15½-in. centres, and therefore 1-lin. ft. of joist A′ supports $\frac{15\frac{1}{2}}{12}$ ft. × 1-ft. $=\frac{31}{24}$ sq. ft. of floor. *Assume*, for the purpose of obtaining its weight, that the size of the joist is 6-in. × 2-in. Hence its weight $=\frac{6}{12}\times\frac{2}{12}\times 1\times 30\text{-lb.}=2\frac{1}{2}\text{-lb.}$ per lin. ft. and the proportionate weight of joist per square foot of floor = weight of joist ÷ area of floor supported by it $=\frac{5}{2}\div\frac{31}{24}=2\text{-lb.}$ (approx.). Therefore, total dead load $=3+2=5$-lb. per sq. ft.

Total load = superimposed load + dead weight
$= 50 + 5 = 55$-lb. per sq. ft.

Portion of floor supported by joist A′ is *abcd* (see broken lines) and its area $=\frac{15\frac{1}{2}}{12}$ ft. × 9-ft. $=\frac{279}{24}$ sq. ft.

Therefore, W (total load) = area × load per sq. ft.

$$=\frac{279}{24}\times 55=640\text{-lb. (approx.).}$$

2. *Bending Moment.*—The load being uniformly distributed,

$$M=\frac{WL}{8}=\frac{640\times 9\times 12}{8}=8{,}640\text{-in.lb.}$$

3. *Sizes.* $M=MR=fZ$. Z is a measure of the shape of the section $=\frac{bd^2}{6}$.

As already stated, $f=800$-lb. per sq. in. for ungraded timber and 1,200-lb. per sq. in. for graded timber; for this example, assume $f=1{,}000$-lb. per sq. in. $Z=\frac{bd^2}{6}$. Assume $b=2$-in.

Therefore, $8{,}640=1{,}000\times\frac{2d^2}{6}$, and $d=\sqrt{8{,}640\times\frac{3}{1{,}000}}=5\cdot1$-in., say 6-in.

The size of the bridging joists shown at A, Fig. 7, is 6-in. × 2-in.

BINDER B′.

1. *Weight.*—The portion of floor supported by binder B′ is *efgh* (see broken lines) and its area is $17\frac{1}{2}\times 9=155$-sq. ft. The dead weight equals that of the floor boards and bridging joists (5-lb. per sq. ft.—see above), together with the approximate weight of the binder per square foot of floor, ceiling joists and plaster. *Assume*, for the purpose of obtaining its weight, that the size of the binder is 15-in. by 6-in. Hence its weight $=\frac{15}{12}\times\frac{6}{12}\times 18\times 30=338$-lb.; this, divided by the area of the floor supported by the binder, equals the additional weight $=\frac{338}{155}=2\frac{1}{2}$-lb. (approx.) per sq. ft. The additional weight of the 4-in. by 2-in. ceiling joists $=\frac{14\text{ (number)}\times 4\times 2\times 9\times 30}{12\ \ 12}\div$ by area of floor $=\frac{210}{155}=1\frac{1}{2}$-lb. per sq. ft.

The approximate weight of ¾-in. thick plaster is 9-lb. per sq. ft. Hence the total dead weight $=5+2\frac{1}{2}+1\frac{1}{2}+9=18$-lb. per sq. ft. Superimposed load + dead weight $=50+18=68$-lb. per sq. ft.

W = area × load per sq. ft. $=155\times 68=10{,}540$-lb. (4·7 tons).

2. *Bending Moment.*—The load may be considered to be uniformly distributed.

Hence, $M=\frac{WL}{8}=\frac{10{,}540\times 18\text{ (effective span)}\times 12}{8}=284{,}580\text{-in.lb.}$

3. *Sizes.* $M=fZ=f\frac{bd^2}{6}$.

$f=1{,}200$-lb. per sq. in. (graded timber—see preceding column). Assume $d=15$-in.

Therefore, $284{,}580=1{,}200\times\frac{b\times 15^2}{6}$

$$b=\frac{284{,}580}{45{,}000}=6\cdot3\text{-in., say 7-in.}$$

The size of the wood binders shown at A, Fig. 7, is 15-in. by 7-in.

[1] In accordance with the L.C.C. Timber Bye-laws, the *minimum* superimposed loads in lb. per square foot are as follows: 40 for rooms of houses, 80 for offices (floors above entrance floor), 90 for offices (entrance floor and those below), 150 for workshops and factories, 200 for warehouses and 50 for flat roofs (with not more than 20° inclination).

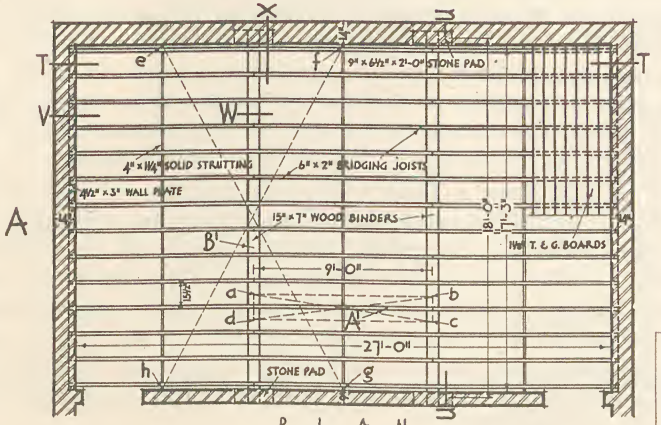
[2] The dead weight includes the weight per square foot of the floor boards and the *equivalent* weight per square foot of a bridging joist.

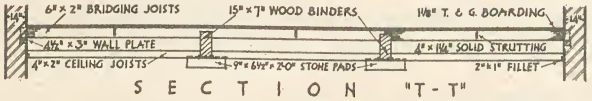
# FLOORS

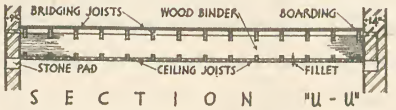
SCALE FOR A,B,C,J,K & L — FEET

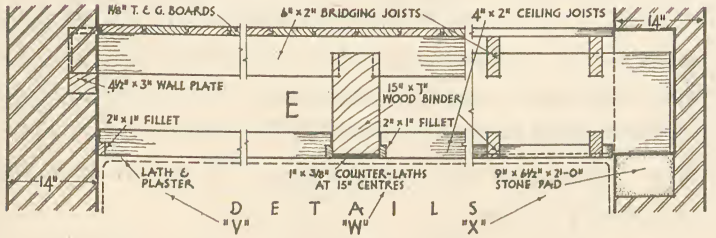
SCALE FOR D,E,F,G,H,M,N,O,P,Q,R & S — FEET

## DOUBLE



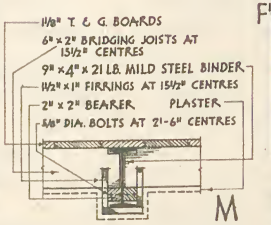


6" × 2" BRIDGING JOISTS
15" × 7" WOOD BINDERS
1⅛" T. & G. BOARDING
4½" × 3" WALL PLATE
4" × 1¼" SOLID STRUTTING
4" × 2" CEILING JOISTS
9" × 6½" × 2'0" STONE PADS
2" × 1" FILLET
SECTION "T-T"



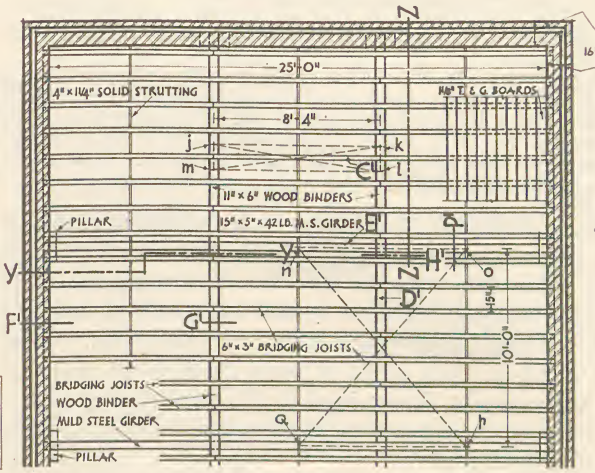


1⅛" T. & G. BOARDS
6" × 2" BRIDGING JOISTS
4" × 2" CEILING JOISTS
4½" × 3" WALL PLATE
15" × 7" WOOD BINDER
2" × 1" FILLET
LATH & PLASTER
1" × 3/8" COUNTER-LATHS AT 15" CENTRES
9" × 6½" × 2'-0" STONE PAD
DETAILS "V" "W" "X"

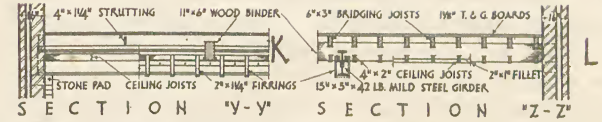
NOTE:
A DOUBLE FLOOR CONSISTS OF TWO SETS OF JOISTS, NAMELY, BRIDGING JOISTS SUPPORTED BY WOOD OR STEEL BINDERS – SEE "A".

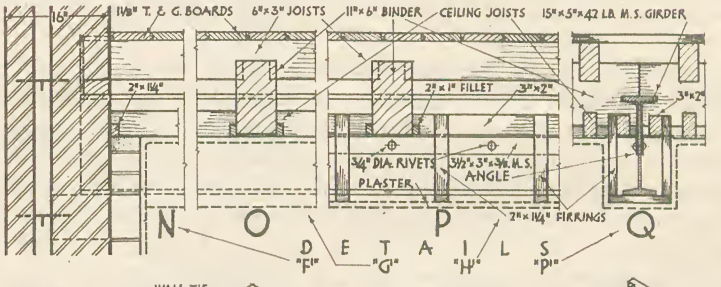
A FRAMED FLOOR CONSISTS OF THREE SETS OF JOISTS, NAMELY, BRIDGING JOISTS SUPPORTED BY WOOD OR STEEL BINDERS WHICH ARE SECURED TO STEEL GIRDERS – SEE "J".

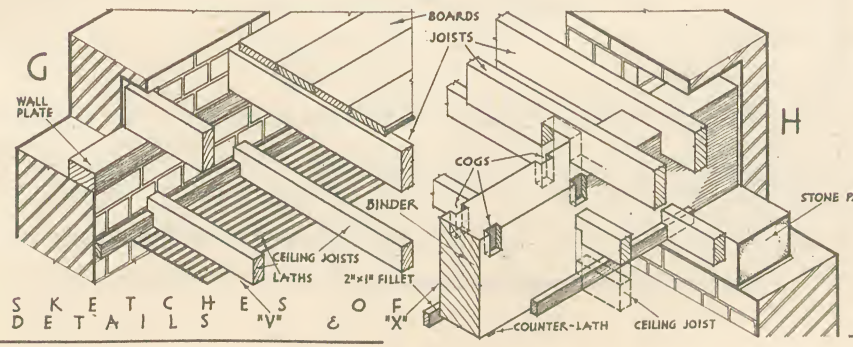

1⅛" T. & G. BOARDS
6" × 2" BRIDGING JOISTS AT 15½" CENTRES
9" × 4" × 21 LB. MILD STEEL BINDER
1½" × 1" FIRRINGS AT 15½" CENTRES
2" × 2" BEARER
PLASTER
⅝" DIA. BOLTS AT 2'-6" CENTRES
ALTERNATE DETAIL "W"

## FRAMED





4" × 1¼" STRUTTING
11" × 6" WOOD BINDER
6" × 3" BRIDGING JOISTS
1⅛" T. & G. BOARDS
STONE PAD
CEILING JOISTS
2" × 1¼" FIRRINGS
4" × 2" CEILING JOISTS
2" × 1" FILLET
15" × 5" × 42 LB. MILD STEEL GIRDER
SECTION "Y-Y"
SECTION "Z-Z"


1⅛" T. & G. BOARDS
6" × 3" JOISTS
11" × 6" BINDER
CEILING JOISTS
15" × 5" × 42 LB. M.S. GIRDER
2" × 1¼"
2" × 1" FILLET
3" × 2"
¾" DIA. RIVETS
3½" × 3" × ⅜" M.S. ANGLE
PLASTER
2" × 1¼" FIRRINGS
DETAILS "F" "G" "H" "P"



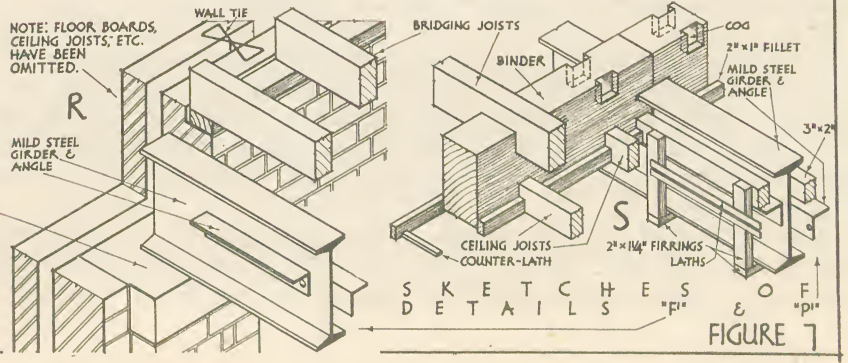




FIGURE 7

If mild steel beams were employed instead of wood binders, the size would be 9-in. by 4-in. by 21-lb. B.S.B. (British Standard Beam). This size is obtained as follows: $M = fZ$. $f$ (for mild steel) = 8 tons per sq. in. Adopting the same M as determined on p. 32, *i.e.*, 284,580-in.-lb. = 127-in.-tons.

Therefore, $127 = 8Z$; hence $Z = \frac{127}{8} = 15{\cdot}88$-in.units.

Structural Steelwork Handbooks are available which contain tables giving data of beams and other sections. Such data include the safe loads which steel beams can support for given spans, moduli of section, etc. Reference to such a book shows that a 9-in. by 4-in. by 21-lb. B.S.B. (which has a Z of 18·03-in. units) will safely support a distributed load of 5·3-tons for a span of 18-ft. This section has been adopted and is shown at M, Fig. 7.

The section at M shows the steel binder with the bridging joists notched at its upper flange and supported on 2-in. by 2-in. bearers which are secured to the web of the binder by $\frac{5}{8}$-in. diameter bolts at 2-ft. 6-in. centres. In this detail, unlike that at E, the bridging joists are lathed and plastered, and the binder is suitably finished by *firring* (or *cradling*), lathing and plastering. Firring consists of two vertical 1 or $1\frac{1}{4}$-in. thick pieces of wood nailed to the sides of each pair of timber joists, and a similar firring fixed to the ends of the vertical members. The plasterers' laths are nailed to this cradling (see S, which shows somewhat similar cradling to a steel girder).

Framed or Triple Floors.—As implied, a triple floor consists of three sets of joists, *i.e.*, bridging joists, binders and girders. In the past the binders and girders were of wood and the former were framed or tenoned to the latter. Girders are now made of steel, and, as already mentioned, this material has to a large extent replaced wood for binders. A framed floor may be adopted when the narrowest span exceeds 24-ft. and the superimposed (live) load is relatively heavy.

Plan, sections and details of a framed floor are shown at J, K, L, N, O, P, Q, R and S, Fig. 7. The plan shows a portion of a large room, the width of which is 25-ft. Steel girders span the room at 10-ft. centres. These support two wood binders at one-third points (8-ft. 4-in. centres), and the latter carry the bridging joists and ceiling joists. The details at P and Q show the binders notched over the top flange of the girder and supported on $3\frac{1}{2}$-in. by 3-in. by $\frac{3}{8}$-in. mild steel angles secured to the web of the girder by $\frac{3}{4}$-in. diameter rivets at 15-in. centres. These angles also support the 3-in. by 2-in. bearers to which the cradling is nailed. Attached brick piers are formed on the 9-in. thick inner leaf of each of the long 16-in. cavity walls to provide adequate supports for the concentrated loads transmitted by the steel girders which are bedded upon hard stone pads. This construction and the steelwork are more clearly shown in the sketch at R. The sketch at S shows the cradling and other details, the former consisting of 2-in. by $1\frac{1}{4}$-in. firrings at 15-in. centres as fixings for the laths (and plaster).

The details of the binders, bridging joists and ceiling joists are similar to those of the double floor. Each 11-in. by 6-in. wood binder may consist of two 11-in. by 3-in. joists bolted together as shown at B and C, Fig. 8, the double row of bolts being staggered; the use of such stock sizes may be preferred if the larger single members are not readily available. If desired, the binders may be lowered and supported by wood bearers bolted to the steel girder; the detail at Q would then resemble that at M or, alternatively, as shown at F, Fig. 8.

The plastered ceiling may be attached direct to the bridging joists, and the binders may then be dealt with as suggested in some of the details in Fig. 8.

If steel is used instead of wood for the binders, it can be shown by calculation (see p. 35) that the size of the steel binders need only be 5-in. by $4\frac{1}{2}$-in. by 20-lb. B.S.B. The use of steel would greatly simplify the details, as the 6-in. by 3-in. bridging joists would just be notched at both flanges of each steel binder, and a flush ceiling would result by simply nailing the laths direct to the joists. If the bridging joists are cut carefully and fitted tightly between the webs of the binders, no other fixing need be provided for the former.

*The advantages of steel over wood for girders will be appreciated when a comparison between the sizes of wood and steel members is made. Thus, a graded timber girder required to support the same load as that taken by the 15-in. by 5-in. by 42-lb. B.S.B. would have to be approximately 20-in. by 12 in. or equivalent, and its weight would be at least half a ton.*

The sizes of the various members of the framed floor illustrated in Fig. 7 were determined in the following manner (see also p. 32).

Bridging Joist C′.

1. *Weight.*—Assume the superimposed load is 100-lb. per sq. ft. Weight of $1\frac{1}{8}$-in. boards = 3-lb. per sq. ft. (see p. 32). Bridging joists are at 15-in. centres, hence 1-lin. ft. of joist supports $\frac{15}{12}$ ft. × 1-ft. = $\frac{5}{4}$ sq. ft. of floor. To obtain its approximate weight, *assume* the size of joists to be 6-in. by 3-in. Hence its weight $= \frac{6}{12} \times \frac{3}{12} \times 1 \times 30$-lb. = 3·7-lb. (approx.) per lin. ft., and the proportionate weight of joist per sq. ft. of floor = $3{\cdot}7 \div \frac{5}{4} = 3$-lb. Total dead weight = 3 + 3 = 6-lb. per sq. ft. Total load = superimposed load + dead weight = 100 + 6 = 106-lb. per sq. ft. Portion of floor supported by joist C′ is *jklm* (see broken lines), and its area = $\frac{5}{4}$ ft. × $8\frac{1}{3}$-ft. = $\frac{125}{12}$ sq. ft. Therefore, W = area × load per sq. ft. = $\frac{125}{12} \times 106 = 1{,}100$-lb. (approx.).

2. *Bending Moment.*

$$M = \frac{WL}{8} = \frac{1{,}100 \times 8\frac{1}{3} \times 12}{8} = 13{,}750\text{-in.lb.}$$

3. *Sizes.*

$$M = MR = fZ = f\frac{bd^2}{6}.$$

Assume the timber is ungraded, with $f = 800$-lb. per sq. in. (see p. 32) and that $b = 3$-in.

Hence,

$$13{,}750 = 800 \times \frac{3d^2}{6}.$$

$$d = \sqrt{\frac{13{,}750}{400}} = 5{\cdot}9\text{-in., say 6-in.}$$

The size of the bridging joists shown at J, Fig. 7, is 6-in. × 3-in.

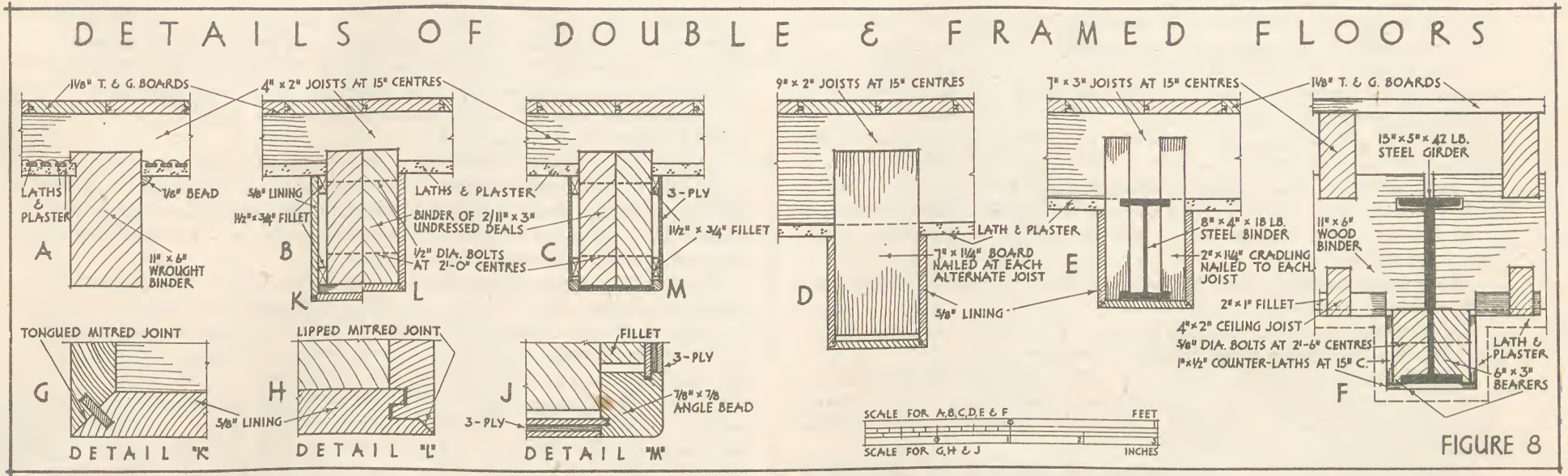



FIGURE 8

BINDER D'.

1. *Weight.*—The portion of floor supported by binder D' is *nopq* (see broken lines) and its area is $10 \times 8\frac{1}{3} = 83\frac{1}{3}$-sq. ft. The dead weight per square foot equals that of the floor boards (3-lb.), bridging joists (3-lb.), binder (*assuming* size is 11-in. by 6-in.; $\frac{11}{12} \times \frac{6}{12} \times 10 \times 30 = 138 \div$ area of floor $= \frac{138}{83\frac{1}{3}} = 1{\cdot}7$-lb.), ceiling joists $\left(\frac{8 \text{ (number)} \times 4 \times 2 \times 8 \times 30}{12 \quad 12} \div 83\frac{1}{3} = 1{\cdot}3\text{-lb.}\right)$ and plaster (9-lb.) = 18-lb. Superimposed load + dead weight = 100 + 18 = 118-lb. per sq. ft.

Therefore, $W = 83\frac{1}{3} \times 118 = 9{,}833$-lb. (4·39-tons).

2. *Bending Moment.*

$$M = \frac{WL}{8} = \frac{9{,}833 \times 9\frac{3}{4} \text{ (effective span)} \times 12}{8} = 143{,}808\text{-in.lb.}$$

3. *Sizes.* $M = fZ = f\frac{bd^2}{6}$.

Assume graded timber, $f = 1{,}200$-lb. per sq. in. (p. 32) and $d = 11$-in.

Hence, $143{,}808 = 1{,}200 \times \frac{b \times 11^2}{6}$.

$$b = \frac{143{,}808}{24{,}200} = 5{\cdot}9\text{-in., say 6-in.}$$

The size of the binders shown at J, P, S, etc., Fig. 7, is 11-in. × 6-in.

If mild steel beams were employed instead of wood binders the size would be determined as explained in connection with double floors and would be 5-in. by 4½-in. by 20-lb. B.S.B. Thus, adopting the same M of 143,808-in.lb. (64·2-in.tons), $Z = \frac{M}{f} = \frac{64{\cdot}2}{8} = 8{\cdot}03$-in.units. A suitable section selected from a steelwork handbook is that mentioned above, having a modulus of section of 10·01-in.units. As already stated, ceiling joists would be unnecessary if steel beams were adopted.

GIRDER E'.

Total M = (*a*) M due to load transmitted by two binders supported at one-third points + (*b*) M due to weight of girder.

$$M_{(a)} = \frac{WL}{6} = \frac{2 \times 4{\cdot}39 \times 25 \times 12}{6} = 439\text{-in.ton.}$$

If a 15-in. by 5-in. by 42-lb. B.S.B. was assumed, its weight = 25 × 42 = 0·47-tons.[1]

Hence, $M_{(b)} = \frac{WL}{8} = \frac{0{\cdot}47 \times 25 \times 12}{8} = 17{\cdot}62$-in.tons.

Total M = 439 + 17·62 = 456·62-in.tons. $M = MR = fZ$. $f = 8$-tons per sq. in.

Therefore, $Z = \frac{456{\cdot}62}{8} = 57{\cdot}08$-in.units.

By reference to handbook, a suitable section is a 15-in. by 5-in. by 42-lb. B.S.B. (Z = 57·13-in.units) and this girder is shown in Fig. 7.

The double and framed floors shown in Fig. 7 have the ceilings flush with the soffit of the binders. Economy results if the ceiling joists are dispensed with and the plasterers' laths are nailed directly to the bridging joists as shown in the several alternative details shown in Fig. 8 and described as follows.

Detail A shows the bridging joists cogged to a *wrought* binder and the laths supporting the plaster nailed to the joists. To prevent unsightly shrinkage gaps, the binder may be grooved to receive the plaster, as shown on the left, or a small

[1] The weight of the angles, cradling, etc., has been ignored.

quadrant bead or cover mould may be introduced (see the right side of the binder). The lower arrises of the binder may be chamfered or otherwise moulded.

Detail B shows the binder consisting of two undressed deals which are bolted together at 2-ft. intervals, the upper bolts staggering with the lower. Two methods of covering the binder are shown. That on the left shows a casing or lining of $\frac{5}{8}$-in. dressed boarding secured to fillets nailed to the binder; the thickness of the fillets varies according to the over-all size and proportion of the binder desired. Alternatively, the lining may be fixed direct to the binder as shown on the right. The joints between the side and soffit lining boards may be either butt mitred, tongued mitred (see detail at G) or, preferably, lipped mitred (see detail at H).

The whole of the casings illustrated in Fig. 8 should be prepared and cramped on the bench to ensure tight-fitting joints.

An alternative casing, consisting of plywood, is shown at C and detailed at J. The angle beads provide an effective finish at the arrises.

A mock beam or binder is shown at D. Short lengths of floor boards, or equivalent, are nailed to alternate joists and the framed casing is fixed to these. This construction does not, of course, strengthen the floor, but it is sometimes adopted for dividing the ceiling into bays.

Detail E shows a wood casing fixed to cradling pieces which are notched over the flanges of the steel binder and nailed to the joists (see p. 34). The joints between the three pieces forming this casing and that at D may be any one of those mentioned above.

The detail at F is alternative to that shown at Q, Fig. 7 (see p. 34). The binders are supported on continuous bearers which are notched over the upper flange of the steel girder and bolted to its web. The sides of the bearers must be counter-lathed as explained on p. 31.

Fire-resisting Floors.—Reference is made on p. 31 to the fire-resisting types of floor construction [1] now employed, in which little, if any, timber is used. Whilst a close study of such construction is outside the scope of the second year curriculum, it is thought desirable to include some of its details here in order that a comparison may be made between the older and relatively modern types of floors.

A, Fig. 9, shows a part-plan of a typical floor of a steel-framed building on which the steel members are indicated in outline. This is sometimes called a *triple* floor, as it consists of three sets of beams, *i.e.*, *filler* or *primary*, *secondary* and *main beams*. The filler beams, usually spaced at not more than $2\frac{1}{2}$-ft. centres, are encased in concrete and are either supportd on, but not fixed to, the top flanges of the secondary beams or are secured to the webs of the latter beams. The secondary beams have steel angle cleats riveted or bolted at the ends, and these cleats are secured in a similar manner to the webs of the main beams. The latter are either riveted or bolted to the steel pillars. Such connections may be welded (see footnote to p. 121, Vol. II) in lieu of cleats and rivets or bolts. The cross-section of a pillar is similar to that of a steel beam. In addition to the filler beams, the secondary beams, main beams and pillars must be encased in concrete or other suitable incombustible material. The sizes of the various steel members depend upon the load to be supported, span, method of fixing, etc. The method employed of determining the sizes of the beams is given briefly in the examples on pp. 34 and 35.

Details of this floor are shown at B, C and the isometric sketch at D, Fig. 9.

In lieu of filler beams encased in concrete, the floor may consist of hollow concrete or fireclay blocks or beams supported on the concrete haunches of steel beams. One example of such a floor is shown at C, Fig. 10. The steel bars are provided to resist tension and shear stresses.

Another type of fire-resisting floor is shown at B, Fig. 10. This portion of a reinforced concrete floor is known as a *slab*. Such a floor may resemble somewhat that shown at A, Fig. 9, with *transverse bar* reinforcement at close spacing in lieu of filler beams. Another set of bars, called *distributing* or *longitudinal bars* are placed at a greater distance apart immediately over and wired to the transverse bars. Various forms of reinforcement—such as sheets of expanded metal—are also used as an alternative to the above circular bars; the expanded metal resembles that shown at A, Fig. 16, Vol. II. The entire floor structure is usually of reinforced concrete. Thus, the secondary and main beams are of concrete, reinforced with steel bars, and the concrete pillars have similar but vertical reinforcement; the pillars may be square, rectangular, octagonal or circular on plan.

Floor Finishes.[1]—The following coverings will be described: (1) wood boards, (2) wood blocks, (3) plywood, (4) parquet, (5) cork and (6) rubber.

1. *Wood Boards.*—A description of this flooring appears on pp. 62-65, Vol. I. As stated, rift or quarter sawn narrow boards are preferred for first-class work, stock nominal sizes varying from 2 to $4\frac{1}{2}$-in. wide by 1 to $1\frac{1}{4}$-in. thick; the width of stock softwood boards used for general work varies from 5 to 7-in. Stock lengths vary from 2 to 16-ft. An attractive flooring is obtained by the use of hardwood boards of random widths, but these must be well seasoned to the correct moisture content if excessive shrinkage is to be avoided. Tongued and grooved boards are chiefly employed; most are square ended, but some of the hardwood boards (*e.g.*, Canadian yellow birch) are t. and g. at the ends.

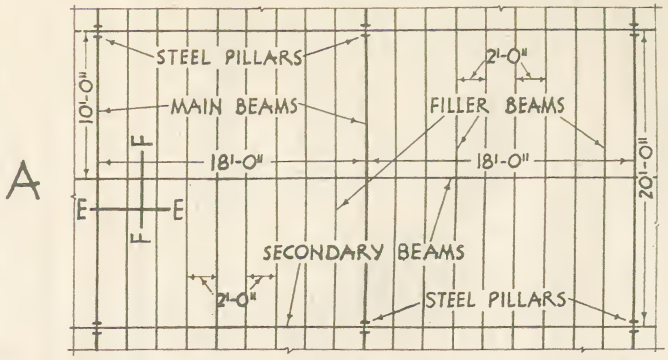
A double floor (see "double boarded floors," p. 65, Vol. I), now much favoured, consists of a sub-floor of 1-in. square edged (or t. and g.) softwood boarding, laid diagonally, and covered with 2 to 3-in. wide hardwood boards which are only $\frac{5}{8}$-in. thick. This thin and narrow covering, which has a very attractive appearance, is known as *strip flooring*; the boards are t. and g. at the edges and ends and are usually secret nailed. One advantage of a double floor is that plastering can be completed and allowed to dry before the top flooring is laid; a common cause of damage to the finished floor is thus eliminated.

The timbers used for flooring include the following softwoods: Douglas

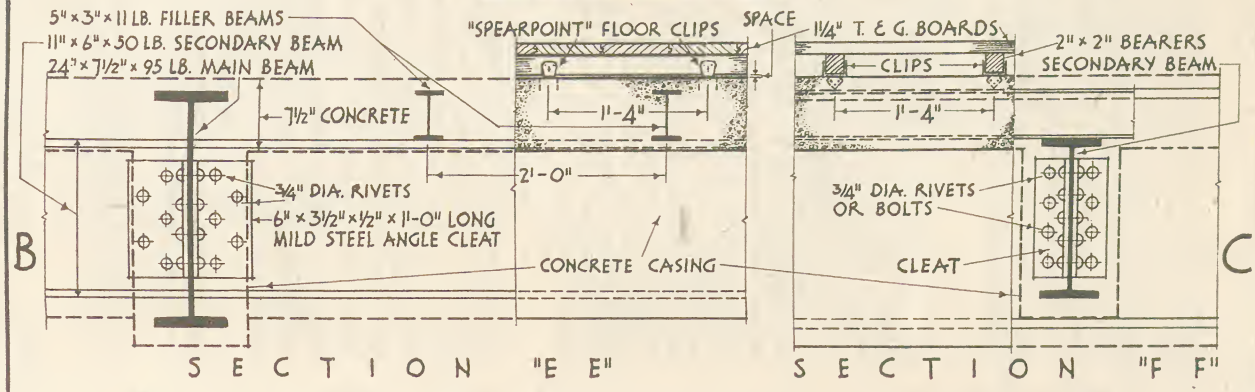
[1] This construction is treated in greater detail in Vol. IV.

[1] Magnesite, terrazzo, tiled, etc., floors are described in Vol. IV.

# FIRE-RESISTING FLOOR

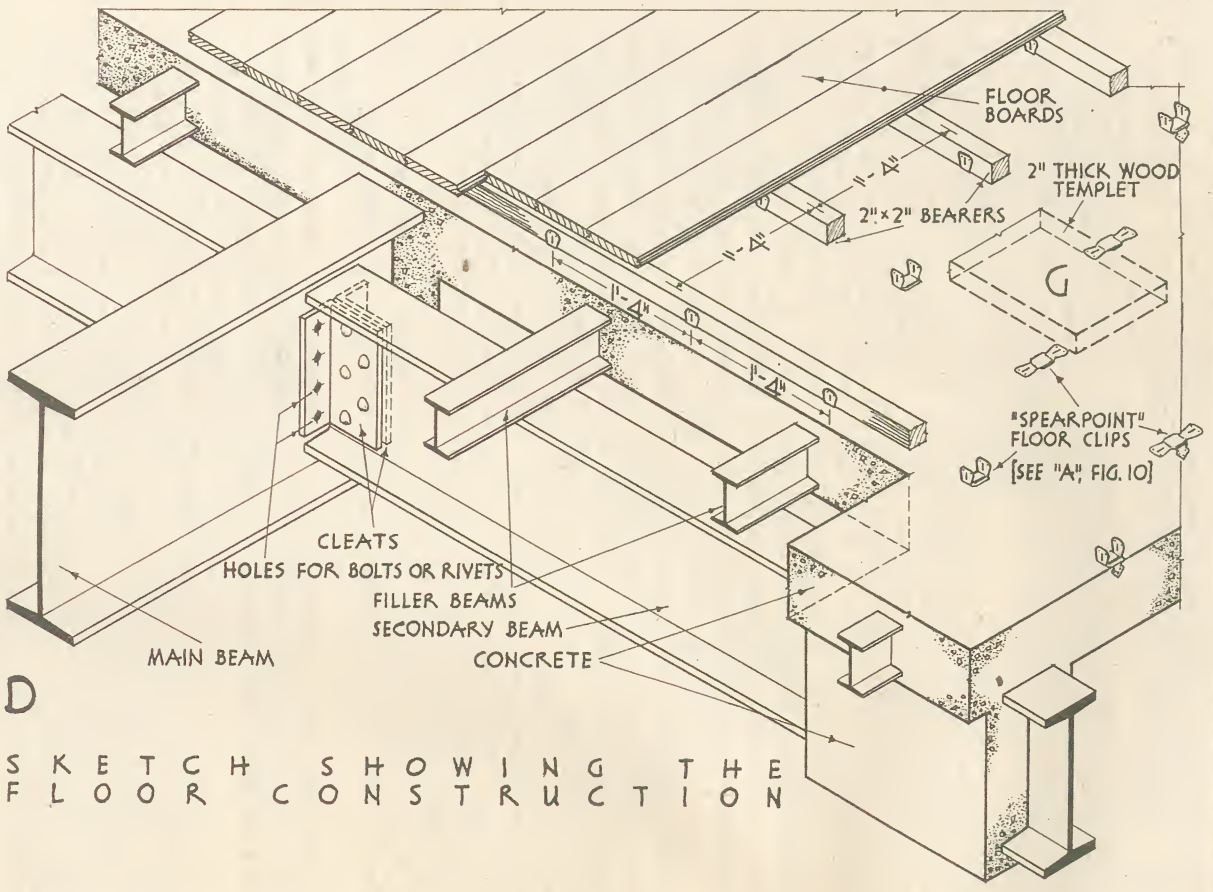



FLOOR PLAN OF A TYPICAL STEEL-FRAMED BUILDING




SECTION "E E"

SECTION "F F"




SKETCH SHOWING THE FLOOR CONSTRUCTION

FIGURE 9

fir, whitewood, redwood, pitch pine, slash pine western hemlock and kauri pine, and the following hardwoods: English, American, Tasmanian and Japanese oak, maple, birch, beech, teak, gurjun, jarrah, seraya and pyinkado. A brief description of these is given in Tables I and II.

Sub-floors of concrete which are finished with wood boards are referred to on p. 65, Vol. I. The boards are shown nailed to splayed fillets or bearers partially embedded in the concrete.

A more recent method of securing the bearers is to anchor them to the concrete by means of *floor clips*. Two patent floor clips are the " Spearpoint " and the " Bull Dog," shown in Fig. 10 at A and D respectively.

The Spearpoint clip is made of 20-gauge mild steel, which is either galvanized or sherardized to prevent corrosion. It is in one piece, having two spear-shaped flanges or legs which are inserted into the concrete, a cross-piece and two upper nailing flanges or ears between which the wood bearers are fixed. Each leg has three projecting holed *bosses* which assist in increasing the bond between the concrete and metal. It is obtainable with the ears bent down and in four sizes, *i.e.*, for 1½, 2, 3 and 4-in. wide bearers; the usual size employed for the average floor is that designed to receive 2-in. square bearers. The clips are spaced in rows at 14 to 16-in. centres, according to the thickness of the floor boards and the weight to be supported, and at 16-in. centres along the rows.

The clips are fixed in the following manner: The legs of the clips are pressed into the concrete within about half an hour after it has been laid and levelled, and before its plasticity has disappeared. Either a plank or a templet (consisting of two long boards with upper cross-pieces nailed at intervals) is used to ensure accurate spacing of the clips in true alignment and the prevention of damage to the surface of the green concrete by the workmen. The ears, being horizontal when the clips are inserted, lie flat on the surface of the concrete and thus present no obstruction to wheeling, etc. operations which are usually carried out when the concrete has hardened. The plank or templet is marked along its edges at 16-in. intervals or other required intervals, and the fixers standing upon it press the clips into the concrete at the divisions. The broken lines at G, Fig. 9, represent a portion of a templet, the width of which equals the distance between the edges of the extended ears in adjacent rows. The clips are sometimes staggered. When the concrete has hardened, the ears are prised by the claw of a hammer until they are vertical (see B, C and D, Fig. 9, and A and B, Fig. 10). The bearers are placed in position between the ears and first nailed through the slots; they are then levelled and, if necessary, packed with small wedges between the underside of the bearers and the surface of the concrete screeding, which may be somewhat irregular. The bearers are finally nailed through the top holes and the floor boards laid in the usual way.

Complete circulation of air round the bearers is assured, as the central portion of each clip is slightly above the concrete (see B, Fig. 9), although if the screeding is imperfect the space between it and the bearers is filled with cement grout. Thus, this method of fixing is an improvement upon that described in Vol. I, where partially embedded fillets are employed. Incidentally, the use of clips results in a saving in the thickness of screed. It is emphasized that the concrete must be dry before the bearers are fixed; the latter should be sound and well seasoned, and, as an extra precaution against the onset of dry rot, they should be thoroughly creosoted before being fixed.

The Bull Dog clip is of 20-gauge sherardized sheet metal and is of H-section (see D, Fig. 10). The standard clip has 1⅝-in. long legs, but if the screeding is less than 1¾-in. thick, clips having 1⅛-in. long legs are obtainable.

They are fixed at the same distance apart and in a somewhat similar manner to that described in the preceding column. Before insertion, the two ears are folded over (see C, Fig. 10) and they are not raised until the floor is ready to receive the bearers; unimpeded use of the floor for walking, wheeling, etc., is thus permitted. Two nails are driven through the upper holes of each ear into the bearers. End joints between the bearers should coincide with the clips, and the lower hole in each ear is to allow an additional nail being driven through at the bearer end. An additional application is shown at E, Fig. 20, Vol. II.

A further development is the " acoustic " type of floor clip. This has a pad of rubber or other insulating material fixed on the cross-piece. The bearers thus rest upon the pads, and a reduction in the transmission of sound through the floor results.

2. *Wood Blocks.*—The following notes are supplementary to those on p. 65, Vol. I. The tongued, grooved and dovetailed wood block shown here at E, Fig. 10, is a type which is much favoured, as the dovetail provides a good key for the hot mastic, and the interlock provided by the tongue and groove prevents the loosening of blocks and the development of an uneven surface. The ends are sometimes tongued and grooved. The sketch at F shows the blocks laid to the basket-weave pattern on a concrete sub-floor, the surface of which must be truly level; another common design is the herringbone. The blocks forming the borders are arranged in a variety of designs; blocks which are stained a different colour to that of the general flooring may be used for borders, or a contrast may be afforded by the use of one or more rows of blocks of different timbers. The border blocks are usually mitred at the corners as shown.

The blocks should be quartered (rift-sawn or edge-grained) to ensure the maximum resistance to wearing action and the minimum expansion and contraction. They should be carefully kiln-dried to the required moisture content (see p. 10), and it is very essential that the building in which they are to be fixed is as dry as possible if good results are to be obtained. Hence the fixing of the blocks in a new building should be deferred until any abnormal moisture in the structure and atmosphere has been removed. Further, the mastic will not adhere to concrete which has not dried out. Adherence of the mastic to the sub-floor is assisted if the surface of the concrete is well brushed to remove the dust and then given a good coat of creosote.

A good test for determining the dryness of a concrete sub-floor is as follows: Approximately 1-sq. ft. of the floor is covered with crystals of calcium chloride. A sheet of glass is placed over them and its edges are sealed with putty. If the crystals are unaffected after three days, the laying of the floor can be proceeded with; otherwise this should be delayed as the dissolving of the crystals indicates the presence of moisture in the concrete.

Wood block flooring is sometimes laid on a cheap wood sub-floor. The surface of the latter is generously covered with the adhesive, a portion at a time;

# FLOOR FINISHES ETC

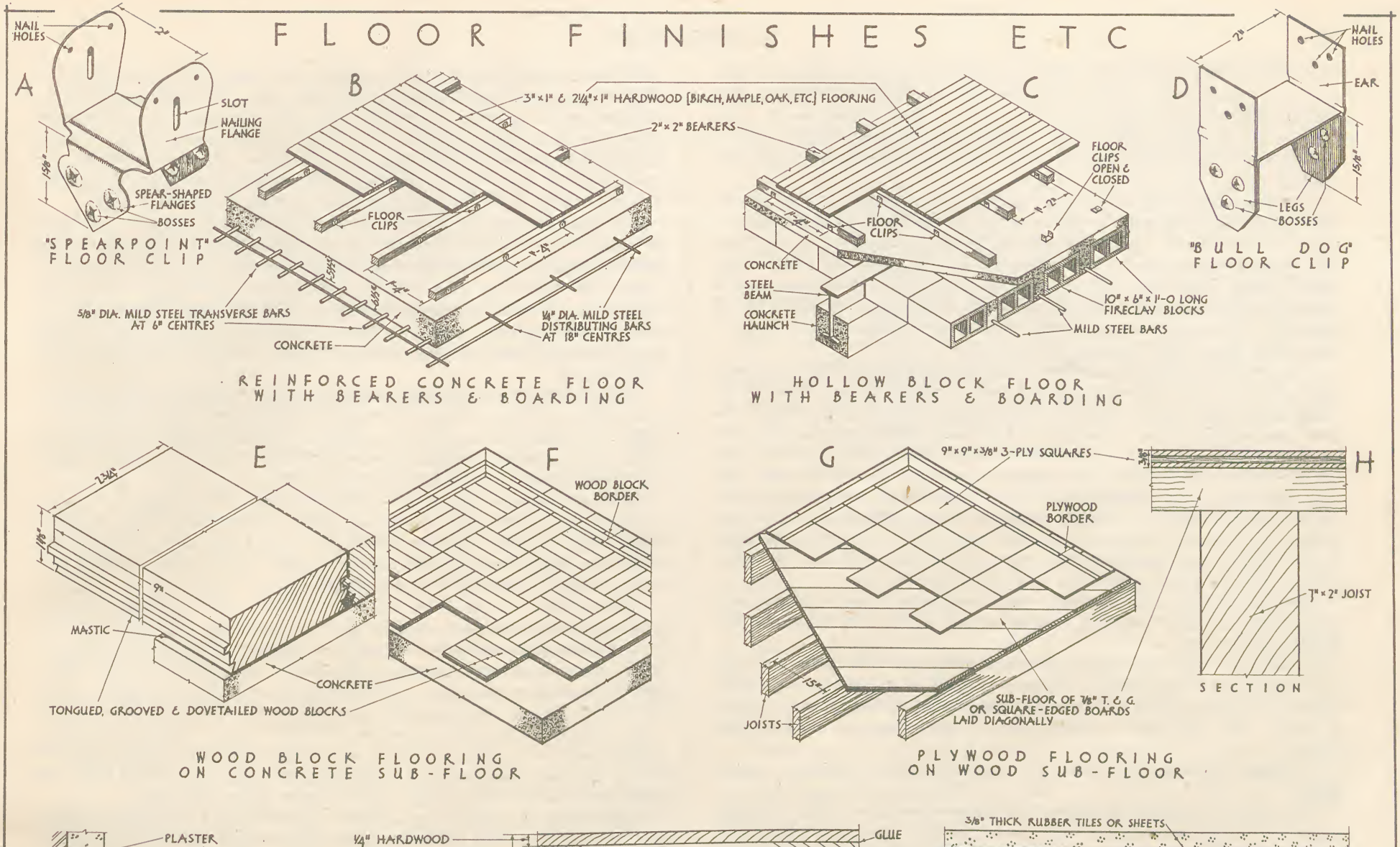



FIGURE 10

each block is then tapped into position and further secured with panel pins which are subsequently punched below the surface, and the small holes stopped with special putty or wood mastic, coloured to conform to that of the wood. The surface is finally planed (large surfaces being usually dressed with an electrically driven portable machine planer), scraped, sand-papered, waxed and polished.

3. *Plywood* (see G and H, Fig. 10).—This is a cheap covering of good appearance, consisting of squares and narrow strips (for borders) cut from boards of 3-ply (see pp. 97-103). The stock sizes of the squares are 9, 12, 18 and 36-in. and from $\frac{3}{16}$ to $\frac{3}{8}$-in. thick; the thicker the surface veneer the better. Oak, birch, walnut, maple and ash plywoods are suitable for this purpose. The plywood can be obtained with the top veneer stained as required for its full thickness. The squares are usually laid with the grain alternating or woods of contrasting colours can be effectively employed.

The covering is laid on a sub-floor of boarding as shown, or this may consist of sheets of $\frac{5}{8}$ or $\frac{3}{4}$-in. softwood plywood (such as Oregon pine), a common size being 48-in. wide and 84 to 96-in. long, depending upon the spacing of the joists (see sub-floor at K). The plywood should be resin bonded (see p. 101) for ground floor sub-floors as a precaution against effects from dampness; the sheets should be well nailed at the edges and at about 12-in. along each joist. The square and strip covering should be well glued and panel pinned in the centre and at about 4-in. intervals round the edges, although the adhesive is sometimes omitted; the pins are punched and the holes stopped as described above. The surface should be well wax polished before use and this should be maintained as a protection to the relatively thin top veneer.

This is rather a noisy covering; the "drumming" can be minimized if strips of felt or similar insulating material are laid on the joists before the sub-floor is fixed.

Existing boarded floors which have defective surfaces can be readily renovated by covering them with plywood squares. If badly worn, the existing surface should be machine planed or levelled up with mastic before the new covering is fixed. This covering is cheaper than a good carpet or linoleum (see p. 41).

4. *Parquet or Parquetry*.—There are two kinds, *i.e.*, (*a*) ordinary and (*b*) inlaid.

(a) *Ordinary Parquetry* consists of thin, small pieces of richly decorative hardwood (chiefly oak and teak) which are hot glued and panel pinned to a softwood or plywood sub-floor, the pins being punched and the holes stopped as described above. The thicknesses are $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$-in., the former being used in most cases and the latter when likely to be subjected to heavy traffic. The pieces are square-edged and arranged according to pattern; sometimes timbers of various colours are made to conform to elaborate designs.

It is advisable to introduce a layer of ($\frac{3}{16}$-in.) plywood between the softwood boarded sub-floor and the parquetry. The plywood boards are nailed to the sub-floor, the joints between them are filled with wood mastic or putty, planed off and sand-papered, and the parquetry is then fixed. The object of this intermediate layer is to afford a perfectly level surface for the thin covering and prevent any movement (expansion and shrinkage) and cupping of the softwood boards being transmitted to the parquetry. Of course, this intermediate layer is not required if the sub-floor is formed of the thicker plywood boards referred to in the preceding column and if the joints between the latter are sealed.

(b) *Inlaid or Plated Parquet* (see K, Fig. 10) is considered to be the best form of this class of covering and consists of a surface veneer of richly figured and coloured hardwood which is glued under great pressure to a softwood backing. The veneer varies from $\frac{3}{16}$ to $\frac{3}{8}$-in. in thickness and the backing is either $\frac{3}{4}$ or 1-in. thick. It is cut into slabs of various shapes and sizes, blocks 1 to 2-ft. square being common. These are glued and pinned to the softwood boarded or plywood (see detail) sub-floor already described; the pins are punched and the holes stopped.

Parquet flooring is surfaced and polished as described in the preceding column.

5. *Cork*.—This is now used extensively for both public and domestic buildings. It is attractive in appearance, durable if properly treated, non-slip even when highly polished, resilient, noiseless, dustless, and can be readily cleaned. It is obtained in the form of (*a*) tiles and (*b*) carpet.

(a) *Cork Tiles* are in squares of various sizes, stock sizes being 4, 6, 8, 9, 12, 18 and 24-in.; special border strips are made, and these are from 1 to 18-in. wide and 36-in. long. The thicknesses are $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$ and $\frac{9}{16}$-in. The colours range from light brown to dark chocolate. The tiles may have tongued and grooved edges or they may be square-edged.

They are laid on both wood and concrete floors. If the former, the sub-floor may be either softwood boards or plywood—see above. The sub-floor must be free from surface irregularities, and it is usually covered with felt paper to prevent any movement in the timber affecting the tiles, which are fixed with a special bituminous mastic and nailed with panel pins at the corners. If, as shown at J, Fig. 10, a concrete floor is to be covered, the screed (composed of 1 part cement to 3 parts sand) must be perfectly level, dry and free from dust; a similar adhesive is used. Skirtings, of various sections and lengths, are made of this material; these are fixed to grounds (see J) and their vertical joints are usually made to coincide with those of the border strips or squares.

After laying, the tiles, if square-edged, are surfaced to a uniform level with a planing or sand-papering machine; tongued and grooved squares do not require this. They are then wax polished.

*Manufacture*.—These tiles are made from the bark of an evergreen species of oak tree which grows in Portugal, Spain, France and countries bordering the Mediterranean. The bark, which grows to a great thickness, is removed every eight or ten years, softened by boiling, scraped, ground, pressed (at 75-tons per sq. ft.) and heated. The heat (which influences the colour) is applied whilst the cork is being pressed and maintained until the resin in it is released and binds the particles together in a dense mass; it is then cut into tiles.

(b) *Cork Carpet* is made in two grades and several qualities and thicknesses. It differs from cork tiles in that the granules of cork when heated with linseed oil, etc., are compressed by rolling on to a backing of canvas, and it is obtainable in 6-ft. wide rolls which vary from 45 to 90-ft. long. The colour also varies according to the pigment added during the process. It is more absorbent than the tiles and is therefore not so easy to keep clean.

Certain proprietary coverings are advertised as cork tiles and carpet, but they more resemble the characteristics of linoleum (see next column) in that their composition (being a mixture of linseed oil, gum, sawdust and pigment, in addition to ground cork) is different and they are harder and more noisy of tread.

6. *Rubber* provides a durable, quiet, flexible, generally non-slip and dustless floor covering which is obtainable in a wide range of attractive colours. It is used for entrance halls, corridors, banks, cinemas, theatres, reading rooms, hospital wards, restaurants, etc.

There are two classes of rubber floor coverings, *i.e.*, (*a*) sheet and (*b*) tiles.

(a) *Sheet Rubber* is obtainable in rolls up to 100-ft. long, 6-ft. wide and $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$ and $\frac{3}{8}$-in. thick; a minimum thickness of $\frac{3}{16}$-in. is recommended for good class work subjected to average traffic. It is divided into (i) ordinary, (ii) combination of ordinary and sponge rubber and (iii) inlaid. The ordinary sheet rubber is of the same material throughout. The second consists of a facing of ordinary sheet rubber backed with sponge rubber. The inlaid variety is of tiles of ordinary sheet rubber, cut to various shapes and of different colours, and arranged to conform to an extensive range of geometrical designs on a rubber backing to which they are vulcanized (see next column). The sheets are invisibly joined.

(b) *Rubber Tiles* are either cut from ordinary sheet rubber or are moulded. They are of uniform thickness, are more resistant to wear and less liable to coil than sheet rubber because of the extra pressure to which they are subjected in the process of manufacture. Tiles are also made having a moulded facing which is vulcanized to an asbestos-cement backing; skirtings of this material are also available.

Rubber may be laid on either a well seasoned wood or a concrete sub-floor.

A wood sub-floor must be adequately ventilated, otherwise dry rot may occur. Plywood (see p. 40) provides an excellent foundation. If boarded, any cupping of the boards or other irregularities must be removed by planing, otherwise they will cause excessive wearing of the rubber covering; for the same reason, nails must be punched and the holes stopped.

If the sub-floor is of concrete, as shown at L, Fig. 10, the level surface of the screed should be given a rough textured finish by the application of the wood float; this gives a good key for the adhesive. The surface *must* be free from dust, and the concrete *must* be thoroughly dry. Most specialist firms give a guarantee for their work, but this will not be forthcoming unless these conditions are complied with.

The rubber is secured to either type of sub-floor by a special adhesive of rubber solution or a moisture-resisting compound.

*Manufacture.*—Rubber is obtained from the latex (a white to cream coloured juice) tapped from certain trees grown in Malaya, Java, Sumatra, Ceylon, Borneo, Brazil and elsewhere. The latex is present in the cells between the bark and cambium of the tree. It is extracted by tapping, *i.e.*, narrow inclined channels leading to a vertical channel or cut are gouged in the bark. The released latex flows down these into a cup fixed near to the ground. The contents of the cups are collected and taken to the factory, where it is strained through sieves to remove any dirt and then coagulated by the addition of acetic acid. It is then passed through washing rollers to free it from impurities, after which the sheets are hung up to dry, smoked over wood fires and finally packed into chests ready for export.

Whilst this crude rubber is the basic constituent of rubber flooring, other ingredients, *i.e.*, fillers (which have a toughening effect in addition to cheapening the process), pigments (to influence the colour), sulphur (necessary for the hot vulcanizing process), etc., are necessary. The crude rubber is reduced to a plastic condition by passing it repeatedly between heated rollers. It is then taken to the mixer where the various ingredients are gradually worked in and thoroughly incorporated by the rollers, and passed between a second set of rollers from which it emerges in a thin sheet. The sheets are now vulcanized, *i.e.*, heated in the absence of air, and pressed. This takes place in a press consisting of several steam heated platens (hollow plates) between which the sheets are placed. The temperature of the plates varies from 100° to 150° C., and the duration of heating varies from a few minutes to three hours, depending upon the degree of hardness required and the composition of the rubber. Rubber tiles are vulcanized in enclosed steel moulds.

CARPET.—There is a tendency towards an increased use of the ordinary woven fabric carpet as a covering material in preference to the hard and noisy timber floor coverings mentioned at (1), (2), (3) and (4). This applies not only to domestic buildings but also to public buildings, now that vacuum cleaning plants are considered an essential part of their equipment, and the difficulty of keeping carpets clean has thereby been overcome. A comparatively cheap softwood boarded floor, together with an underlay of felt, is all that is necessary if a " fitted carpet " (*i.e.*, one that covers the whole area of the floor) is used. If a hardwood surround to a centrally placed carpet is required, an effective finish is obtained by covering the margin between the walls and the carpet with $\frac{1}{4}$-in. thick plywood blocks or strips, as described in (3). This surround should not be fixed to the softwood floor until the carpet has been in use for several weeks and has thereby been stretched.

LINOLEUM AND CELLULOSE FLOORING are laid upon either timber or concrete floors. Linoleum consists of a mixture of linseed oil, gum resins, cork dust, sawdust and pigments; this mixture is spread on to a backing of jute canvas and hot rolled. Cellulose flooring is made in the same manner and of similar materials, except that the base is of gelatinized nitrocellulose instead of linseed oil and resin. The British Standard Specification, No. 810, divides plain linoleum into three types and nine thicknesses varying from 1·9 to 6·7 mm. (approx. $\frac{1}{12}$ to $\frac{1}{4}$-in.); the rolls are 6-ft. wide. Cellulose flooring is in three grades—$\frac{3}{32}$, $\frac{1}{8}$ and $\frac{1}{4}$-in. thick—and is in 6½-ft. wide rolls. An adhesive should be used for securing each covering to either type of floor. Concrete floors must be perfectly dry before being covered, and a timber floor covered with such an impervious material as linoleum must be adequately ventilated.

## PARTITIONS

Partitions are walls, usually relatively thin and of light construction, which are used to divide buildings into rooms, corridors and cubicles. Whilst their essential purpose is to serve as divisions, partitions may also be utilized to support the joists of floors, purlins and ceiling joists of roofs, etc., and as such are load-bearing structures.

The many materials used in the construction of partitions include (1) timber, (2) clay and terra-cotta, (3) concrete, (4) plaster, (5) asbestos-cement, (6) glass and (7) metal.

1. TIMBER PARTITIONS.—These include (*a*) stoothed and (*b*) trussed partitions.

(a) *Stoothed Partitions*.—These are also known as *stoothings*, or *stud*, *quarter* or *common partitions*. This type is illustrated in Fig. 11. It consists of vertical members called *studs* or *quarters*, which are secured to two horizontal lengths of timber, the upper being the *head* and the lower the *sill*. One or both sides may be either lathed and plastered, or covered with boarding, plywood sheets, wall boards, etc.

The studs, usually of 4-in. by 2-in. and occasionally of 3-in. by 2-in. stuff, are spaced at 14 to 16-in. centres for lathing and up to 2-ft. centres for boarding or panelling. Short lengths of studs, such as those above doors, are called *puncheons*. The ends of the studs may be either stub-tenoned into the head and sill (see E and L), or housed, or, as shown at J, slotted over 1½ or 1-in. by 1-in. fillets nailed to the head and sill. In cheap work the sill is sometimes omitted and the studs are nailed direct to the floor (see U). The studs are stiffened by *nogging pieces* or *noggings* at vertical intervals of from 3 to 4-ft. These short pieces, 4 or 3-in. by 2 or 1½-in., are generally fitted more or less horizontally and tightly between the studs, to which they are nailed (see O and G), or inclined as shown at Q; alternatively, the noggings may consist of pairs of 2-in. by ¾-in. continuous pieces let in flush with the faces of the studs (see T and H). The wall studs may be packed out from the walls as shown at A, or securely plugged to the walls.

The width of the head and sill is the same as that of the studs and are preferably 3-in. thick. The former is securely nailed to the ceiling (or floor) joists and the sill is fixed to the floor. Sometimes these members have their ends built into the walls, but, apart from the difficulty in accomplishing this, it is unnecessary if they are securely fixed as described. The head and sill are shown at right angles to the floor and ceiling joists. If the partition is to be fixed parallel to the joists, it should be either placed immediately over a floor joist (or doubled joist) or, where this is not possible, on short 6-in. by 2-in. transverse bearers housed at about 3-ft. centres between the pair of joists concerned; similar 4-in. by 2-in. bearers between the joists of the ceiling or upper floor will serve as a fixing for the head.

If provision has to be made for a door, as shown at A, the door posts should be sufficiently rigid to resist the impact of the door and they should be continuous

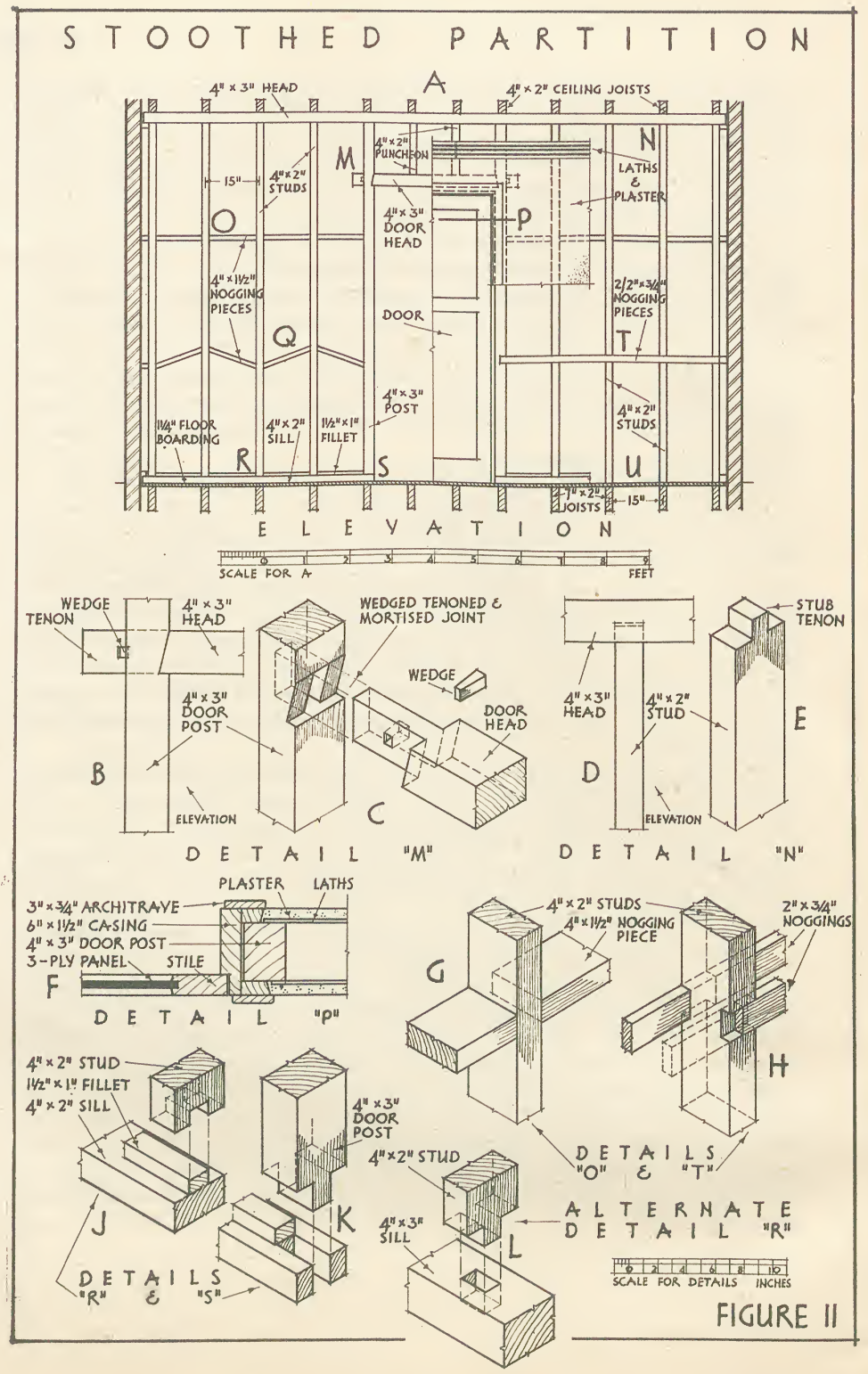



FIGURE 11

from floor to floor (or ceiling). Those at A are of 4-in. by 3-in. stuff. The top of each post is tenoned to the head and the foot is usually slot tenoned as shown at K. The wedged tenoned joint shown at A, B and C affords an effective connection between the door head and post. Ample space must, of course, be allowed at the door opening to receive the casing, and either wedges are driven or blocks are fixed between the casing and framing. A detailed part plan of the door is shown at F.

This class of partition is in common use. Because of its lightness, it is usefully employed when there is no supporting wall below. Its efficiency in preventing the transmission of sound is at least equal to that of a solid 4½-in. brick wall (see p. 48). Sanitary fittings, such as certain lavatory basins, and heavy fixtures cannot, of course, be supported by this type of structure, and the hanging of pictures presents a difficulty unless their means of support are secured to studs or noggings. An additional disadvantage is its deficient fire-resisting quality; its capacity for harbouring vermin is a further defect, especially in certain classes of property.

Examples of stoothings are shown in Figs. 14, 15 and 34.

Another form of this class of structure in which studs are employed is the *brick-nogged partition.* This is practically obsolete. It consists of studs and panels of brickwork between, the former being placed at three or four stretchers apart. The studs are 4½-in. by 3-in. when the brickwork is 4½-in. thick, and of 3-in. square stuff if the bricks are laid on edge. Nogging pieces or bonding strips, 4-in. by ½-in., are housed into the studs at 2 to 3-ft. vertical intervals. The object of the studs and bonding strips is to increase the rigidity of thin brick walls, especially long and high walls. This object can be more readily effected by the use of metal reinforcement, and hence reinforced brickwork (see p. 45, Vol. II) and the fire-resisting partitions described on p. 45 have superseded the brick-nogged type.

(b) *Trussed or Framed Partitions.*—These are seldom employed nowadays except for buildings of a temporary or semi-permanent character, or in those countries where timber is abundant and can be readily and cheaply obtained. Preference is now given to the use in this type of structure of materials of high fire-resisting and insulating qualities, many of which can be speedily erected.

Trussed partitions are designed to be self-supporting. They may also be required to carry one or more floors and ceilings. They are illustrated in Fig. 12.

A truss is a combination of members forming a rigid framework, and a trussed partition is therefore a triangulated structure composed of at least a head, sill, posts, inclined members called *braces* or struts, and studs (with noggings) spaced according to the nature of the covering material to be applied. An intermediate horizontal member, called an *intertie*, is usually provided in partitions exceeding 10-ft. in height. In addition to transmitting a portion of the load direct to the sills, an intertie has the effect of reducing the length and consequently the scantlings of the braces and posts, and of increasing the rigidity of the frame.

The partition at A supports two floors. In addition to the wood members already described, it has two long wrought iron or mild steel rods which pass through the sill, intertie and head. *Both* ends of each rod are *tapped*, *i.e.*, screw-threads are formed, and provided with nuts and washers. Close timber joints are assured when the nuts are tightened.

The braces, being in compression, assist in transmitting the weight to the walls. The sill, like a tie beam of a king post roof truss (see p. 76, Vol. I), forms a tie and is in tension. The head acts as a *straining beam* (see the queen post roof truss in Fig. 18) for the braces, forms a fixing for the posts and studs, and supports the floor joists which are cogged to it (see H, Fig. 7). In order to avoid transverse stresses, the centre line principle should be observed wherever possible when setting out the members at the joints (see details at C, E, F, K, O and P. Satisfactory bearings for the sill, head and intertie are obtained if their ends are supported on 3 to 6-in. thick hard stone pads, as shown.

The left side of the elevation at A shows a typical arrangement of the studs when the partition is to be plastered. The edges of the braces should be chamfered to reduce the width of the faces next to the plaster to at least 3-in. in order that an adequate key for the plaster is obtained (see p. 31). For braces of greater width than 4-in., laths are nailed centrally along each outer face; the ordinary horizontal laths are nailed over these and bent down over the studs; the intertie is counter-lathed with short vertical pieces of laths spaced at 15-in. centres. The right side of the elevation shows the partition boarded. For this and similar treatment, such as plywood, etc. panelling, the studs and noggings are so spaced to provide the necessary means for fixing the covering.

Alternative details showing the connection between an upper brace, post and head are illustrated at C and D. The former shows the centre line principle of setting out, the brace and post being respectively bridle jointed and mortised and tenoned. The alternative detail at D shows an additional member, a *straining piece*, which is sometimes introduced to increase the rigidity at the heads of the posts.

The detail at E shows the connection between the two portions of the post, the lower brace and the intertie. The studs are stub-tenoned into the latter and notched over 1-in. square fillets at the brace (see F). In cheap work the ends of the studs are cut to the required bevel and nailed to the brace.

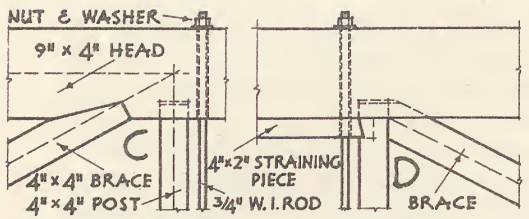
In the detail at F, the foot of the brace is bridle jointed to the sill and a ½-in. diameter wrought iron bolt is provided to make a rigid connection. The seating block shown is preferred to the alternative of notching the underside of the sill for the washer, as the latter would unduly weaken the sill. The section at G shows the 1-in. square fillets which are nailed to the brace and over which the ends of the studs are notched.

Just before the covering material is applied or fixed, the tension rods are given a final tightening by applying a spanner to the nuts. This is to ensure close joints, which may have opened slightly during the erection of the partition and owing to shrinkage of the timbers.

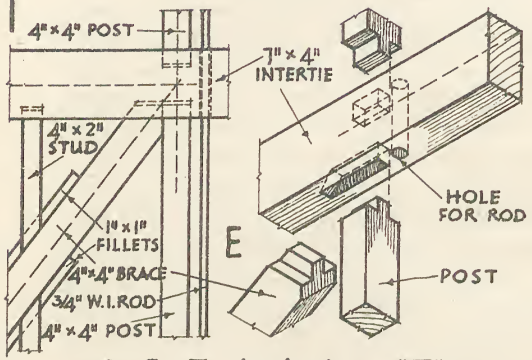
In lieu of the tension rods, wrought iron straps, such as are shown at K, O and Q, may be fixed at R, T and at the connection between the post and sill

# TRUSSED PARTITIONS

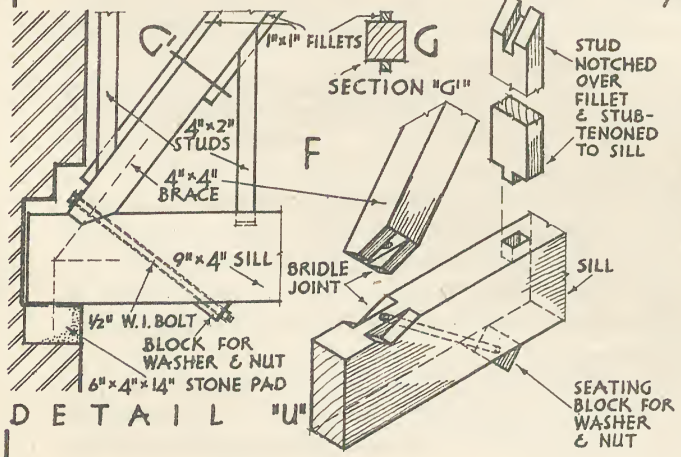
## DETAILS OF PARTITION "A"



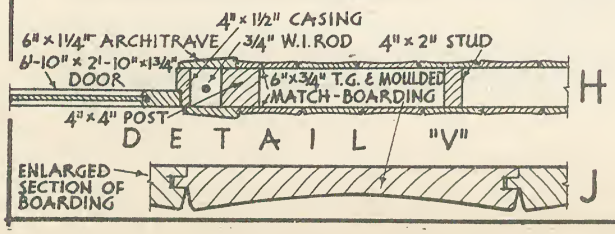

ALTERNATE DETAILS AT "R" & "S"




DETAIL "T"

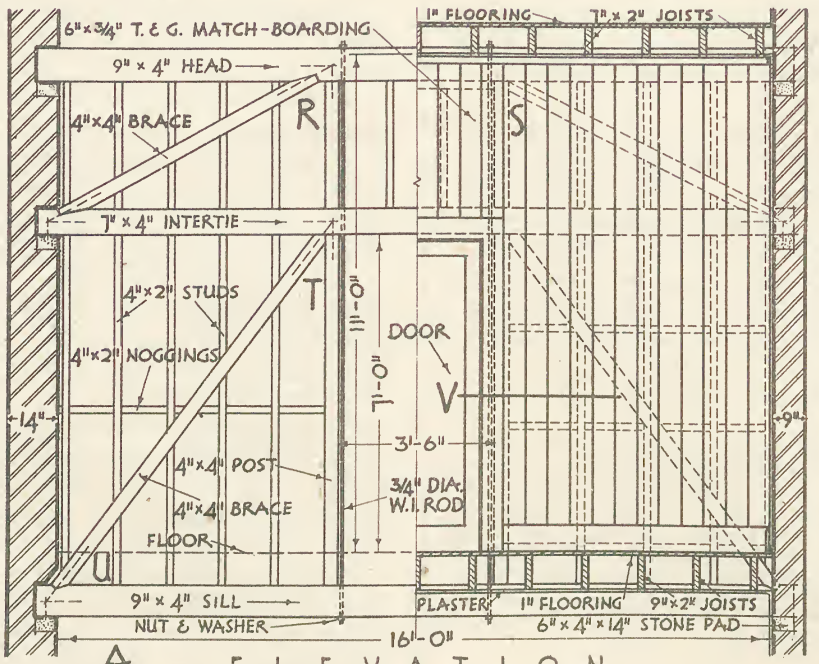



DETAIL "U"

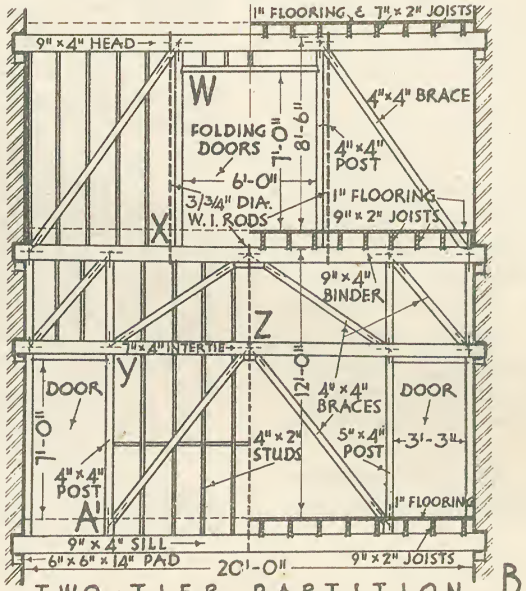



DETAIL "V"



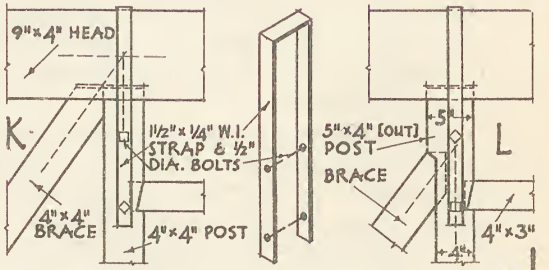




A ELEVATION

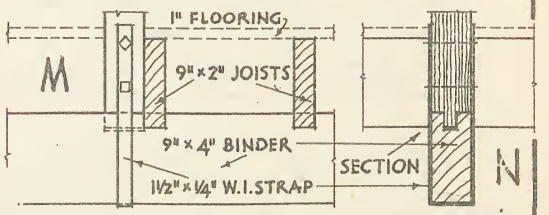



TWO-TIER PARTITION B

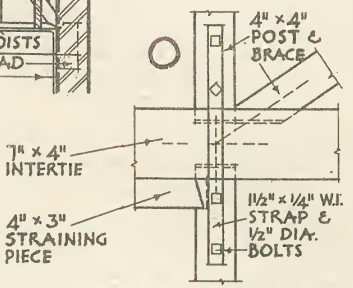
## DETAILS OF PARTITION "B"



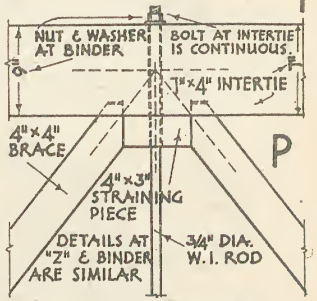

ALTERNATE DETAILS AT "W"



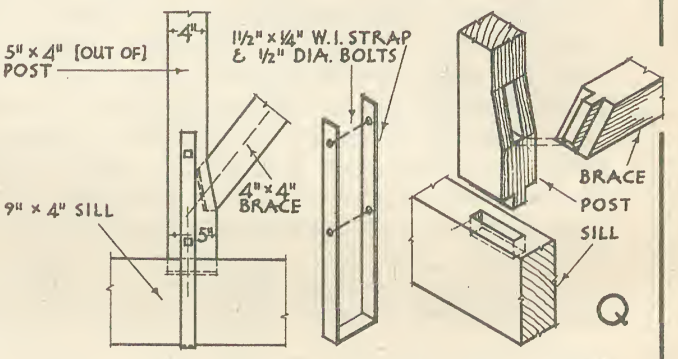

DETAIL "X"




DETAIL "Y"




DETAIL "Z"




DETAIL "A'"

FIGURE 12

respectively, in addition to similar straps at the corresponding connections of the opposite post. Such straps are less effective than the rods owing to the absence of provision for final tightening.

A sectional plan through a portion of the door, etc., is shown at H, and an enlarged section of the match-boarding is shown at J. Ordinary t. and g. vee-jointed boarding in narrow widths, or plywood sheets (as shown in Fig. 40), etc., may be preferred. As already mentioned (p. 43), the door casing must be well secured to the posts and head (intertie), blocks as required being packed between.

A two-tier trussed partition, *i.e.*, one that extends through two stories, is shown at B. Provision is made for two side doors in the lower storey and a central door in the upper. The partition supports three floors. Details are shown at K, L, M, N, O, P and Q. The various metal straps may be omitted if the three wrought iron or steel rods shown by broken lines at B (a central one at the lower storey, which extends from the sill to the binder, and two at the upper storey, from the binder to the head) are provided. There are several alternatives to these details (*e.g.*, a $\frac{3}{4}$-in. diameter bolt may be substituted for the stirrup strap at Q—see Fig. 40, Vol. I—and in the same detail, and for economy, a shaped cleat may be well nailed to a 4-in. by 4-in. post to form an abutment for the brace) which are typical of timber jointing as applied to partitions and framed carpentry generally. Also, as explained in connection with the design of floors, the sizes of the various principal members of a truss vary according to the load to be supported, span, etc.

Multi-ply boards and laminboards (pp. 98 and 103) provide additional examples of the use of timber for partitions and screens.

2. Clay and Terra-cotta Brick and Block Partitions.—The commonest type of clay partition is, of course, the ordinary solid brick wall of $4\frac{1}{2}$-in. (or 3-in. if laid on edge) or more in thickness. Whilst such walls are relatively strong and fire-resisting, their weight precludes their use for partitions on upper floors unless provision in the form of girders or lower walls is made for their support. Hence several manufacturers have turned their attention to the production of clay units, either bricks or blocks, which are comparatively light and yet are sufficiently strong for the construction of non-load bearing partitions. Lightness is obtained either by making them hollow and/or by using diatomaceous earth which produces units having a very porous structure.

Examples of hollow bricks are illustrated at V and W, Fig. 5, Vol. II.

An example of a hollow block is shown here at A, Fig. 13. The tongues and grooves on the beds assist in making the joints rigid and facilitate erection. The grooved faces afford a good key for the plaster. Some blocks are made without keyed faces, and these may be glazed on one or both sides in a variety of colours for use as partitions in lavatories, etc. The sizes are specified in the figure ; solid blocks are also made which are only $1\frac{1}{2}$-in. thick. In general, the blocks are built in either cement mortar or compo and are bonded in the usual way with staggered vertical joints. A good form of hollow block is shown at Y, Fig. 5, Vol. II (see also pp. 17 and 19 of that volume). Hollow blocks are made of gault clay, fireclay (these two are described on pp. 1 and 17, Vol. II), terra-cotta (from carefully prepared clay or shale, moulded, dried, sometimes glazed, and burnt) and diatomaceous earth.

The following are the merits of these blocks : Satisfactory mechanical strength, lightness in weight, good heat and sound insulation, fireproof, non-shrinkable and vermin proof. Those made of diatomaceous earth can be sawn to required size and shape and provide a firm hold for nails and screws.

A patent pressed clay brick, manufactured by the London Brick Co. Ltd., and employed in the construction of partitions, is shown at M, Fig. 13. These bricks are bedded in cement mortar (composed of 1 part Portland cement and 4 parts sand) in bonded courses with half-brick laps. When so constructed, the diagonal grooves—of approximately $\frac{1}{16}$-in. depth—are in continuous alignment from top to bottom. The $\frac{1}{8}$-in. thick vertical joints are left free from mortar. Short lengths (extending over two and a half courses) of 14-gauge galvanized mild steel wires are fixed in the diagonal grooves as the work proceeds and on completion of each second course. The bent upper ends of the wires are hooked over the bed grooves of the bricks, and their lower ends are hooked under the preceding wires. Under normal circumstances, and for partitions up to 15-ft. high, only single reinforcement is required, *i.e.*, the wires are run on each side of the wall from bottom to top and from left to right, as shown by broken lines ; double reinforcement is required for larger partitions, up to 30-ft. by 30-ft., the wires being fixed in both grooves and on both sides, and thus running both right and left. On completion of the laying of the bricks and fixing of the reinforcement, both sides of the partition are rendered in cement mortar of 1 : 3 mix. Although these partitions are only 2-in. thick, excluding the rendering, they are very strong and resistant to side pressure or vibration. These bricks are also used for cavity walls consisting of two 2-in. thick leaves and a 2-in. cavity. In such walls the diagonal wires are only fixed on the outer faces of the leaves and normally only single reinforcement is required. In addition, it is recommended that three rigid galvanized wrought iron wall ties be used per square yard of walling. Both sides of the wall are rendered in cement mortar.

The construction of this patent partition is facilitated if a temporary " timber liner " is fixed. That recommended consists of 3-in. by 2-in. studs fixed at 3 to 4-ft. apart, to which 3-in. by $\frac{3}{4}$-in. wood slats are nailed at $13\frac{1}{2}$-in. centres. The patent bricks are then built-up against the slats, and a saving in plumbing thus results. If several partitions have to be constructed, the liner may consist of a frame of the above members which can be readily removed and erected.

3. Pre-cast Concrete Slab and Block Partitions.—The relatively thin units used for non-load bearing partitions, usually composed of lightweight concrete (p. 29, Vol. II), are referred to as " slabs," whilst the thicker units, intended for the construction of external walls, load-bearing partitions, and the backing of brickwork and masonry, are generally known as " blocks."

Concrete slabs, whilst strong enough for the purpose, should be as light as

possible, otherwise special provision would be required for their support. Hence, a suitable material is lightweight concrete consisting of a mixture of Portland cement (or Portland blast-furnace cement or aluminous cement) and aggregates such as clinker, coke breeze, pumice, foamed slag and expanded slate. These aggregates are described on p. 29, Vol. II. The composition varies from 6 to 12 parts aggregate to 1 part cement by volume; sand is sometimes added. The aggregate must be crushed to pass through a ½-in. sieve. Both solid and hollow slabs are made.

The solid type at B, Fig. 13, is that referred to in the British Standard Specification, No. 492—1933; there are many sizes, but the standard dimensions are $17\frac{3}{4}$ and $23\frac{3}{4}$-in. by $8\frac{3}{4}$ and $11\frac{3}{4}$-in. by 2, $2\frac{1}{2}$, 3 and 4-in.; the radii of the tongue and groove are $\frac{7}{16}$ and $\frac{9}{16}$-in. respectively. The hollow type is covered by the British Standard Specification, No. 728—1937, and the specified sizes are similar to the above, with a minimum thickness of $2\frac{1}{2}$-in. That at C is one type of cellular slab; others have rectangular voids and some have tongued and grooved vertical edges.

Slabs are made on a large scale by hand-operated machines of which there are several types. The concrete, machine mixed, is fed into a steel box of the moulding machine after a wood pallet has been placed inside on the bottom; after consolidation by means of a steel plate, operated by a hand lever, the pallet with the slab is automatically ejected by operating a foot pedal and taken to the drying shed to fully mature for preferably three months and not less than four weeks. Thorough maturing is essential if cracks in partitions due to shrinkage of the concrete are to be avoided. Lean mixes (*i.e.*, when the concrete mix is not richer than 1 : 8) also reduce the tendency for cracks to develop. Hollow slabs are moulded in boxes containing cores, and consolidation is effected by vibration of the pallet and by pressure applied at the top and bottom; the slabs are extruded over the cores. Approximately one hundred and six slabs can be moulded per hour by one type of machine.

The concrete is also hand compacted with a metal tamper in lieu of the plate. Alternatively, slabs are cast in wood frames and simply compacted with the back of the shovel.

Concrete slabs are bedded and jointed in cement mortar. Plastering of the surfaces (some slabs only require one coat of plaster on each side) completes the partition.

The slabs can be readily cut with a bolster or broad chisel, and most (excluding clinker slabs) will firmly hold screws and nails.

Some concrete slabs, such as pumice, have good fire-resisting qualities, but others (*e.g.*, coke breeze) are combustible. Because of their porous nature, lightweight concrete slabs have a good heat insulation value, but they are not very resistant to the passage of sound.

Pre-cast concrete blocks are made in a similar manner to the slabs. Gravel and broken brick or stone are used as aggregates, in addition to those employed for lightweight concrete. They are generally used for load-bearing partitions in addition to walls. The British Standard Specification, No. 834—1939, applies to these blocks. Their standard dimensions are $17\frac{3}{4}$-in. by $8\frac{3}{4}$-in. by 4, $4\frac{3}{16}$, $4\frac{1}{2}$, $8\frac{3}{4}$ and 9-in.; blocks not exceeding $4\frac{1}{2}$-in. in thickness may also be obtained in $23\frac{3}{4}$-in. lengths. The mixture shall consist of not more than 1 : 6 by volume,

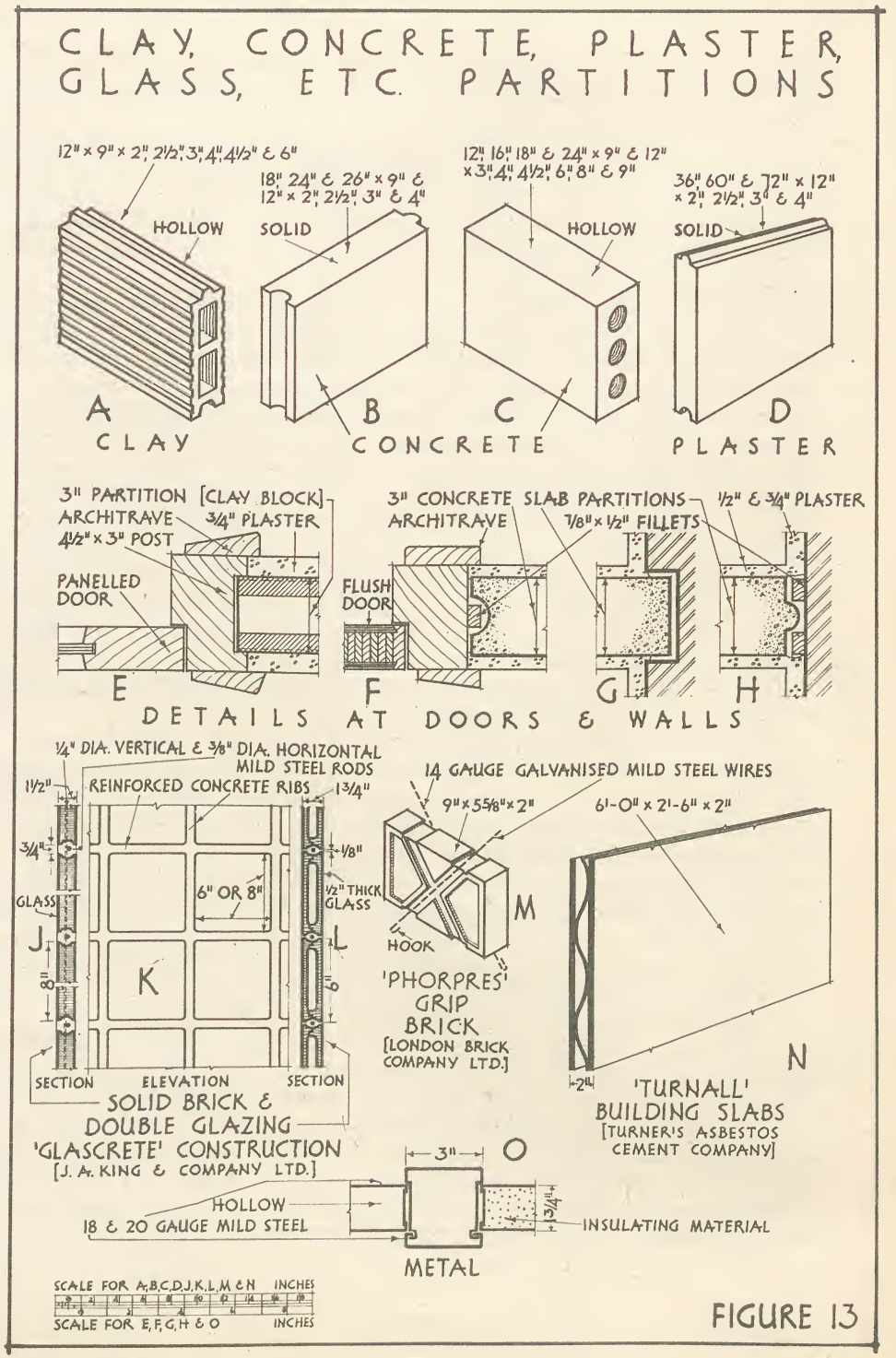



FIGURE 13

unless the webs of the blocks are 1-in. or less in thickness when a 1 : 4½ mix may be used.

A relatively new concrete product which is being used to an increasing extent for the manufacture of slab partitions is known as *wood-wool cement* or *fibrous wood cement*. This consists of a mixture of wood-wool (wood shavings) and Portland cement ; gypsum may be added. Long shavings from ⅛ to ¼-in. wide are coated with liquid cement, consolidated into slabs by means of a machine press, and are then stored to mature. These slabs are very light, the average weight of the material being only about 30-lb. per cub. ft. ; brickwork weighs from 100 to 140-lb. per cub. ft. Further, the slabs have good heat and sound insulation qualities, are highly fire-resistant (the cement coating serving as a protection to the wood shavings), can be easily fixed and sawn, and provide a good key for the plaster which is applied to the surfaces after fixing. The slabs of Thermacoust,[1] illustrated at N and V, Fig. 14, are made of this material, their dimensions being 84-in. by 23⅝-in. by ½, ¾, 1, 1½, 2, 2½, 3, 4 and 5-in. The thicknesses recommended for partitions are 2 and 3-in. when the height does not exceed 8 and 10-ft. respectively. The slabs are bedded and jointed in ordinary lime mortar or, frequently, gypsum plaster, and the vertical joints are staggered. The surfaces are covered with two coats of plaster. See p. 49.

Efficient slabs and blocks suitable for partitions are made of *sawdust concrete*, so called because it is a mixture of cement and sawdust. Besides being light in weight, these units have a satisfactory heat insulation value, they will take nails and screws, and they can be readily cut or sawn. They have a tendency to expand and shrink, and cracking or crazing of the plaster covering may result.

Another type of lightweight slab is made of *aerated* or *foamed cement*. This material is produced by adding water to a mixture of cement and powdered aluminium ; hydrogen gas is evolved, an increase in bulk results and the structure becomes a mass of small voids separated by films of cement. A similar result is achieved if a soapy liquid substance is used as the foaming agent and stirred briskly with the cement.

> Briefly, slabs of aerated cement are made in the following manner : Portland cement and powdered aluminium in the proportion of 1 : 1,000 by weight are mixed and water is added. A metal mould is partially filled (to approximately one-third its depth) with this liquid paste, which gradually rises to completely fill the mould. The upper surface is trowelled smooth after any excess has been struck off ; the slab is then allowed to harden in the mould.

This is an excellent material for the construction of non-load bearing partitions, although shrinkage cracks will occur if the slabs are not thoroughly matured.

Time and labour are saved in erecting concrete slab partitions if temporary wood liners or frames are employed as described on p. 45, the horizontal slats being fixed at centres to suit the height of the slabs. Otherwise each slab has to be carefully plumbed.

[1] Proprietors : The Cementation Co. Ltd.

4. Plaster Slab Partitions.—These are made of calcium sulphate (burnt gypsum or plaster of Paris). This is mixed with water, and sand may be added to the mix. The slabs are made by casting the material in wood or metal moulds. They set very quickly. One form of slab is shown at D, Fig. 13. Whilst many slabs are cast without tongues and grooves, the rigidity of partitions is increased if such provision is made. The vertical edges are also sometimes tongued and grooved. In order to decrease their weight, many of the thicker slabs at least are cellular and resemble that shown at C. Sawdust is also sometimes added to reduce their density.

There is a big range of sizes, but those specified at D are common. The slabs are bedded and jointed in lime mortar ; hair (1-lb. of hair to 3-cub. ft. of lime) and plaster of Paris (usually 10 per cent.) may be added. Those cast in metal moulds are smooth faced and are not subsequently covered with plaster. When the partitions are to be plastered, the plaster slabs are cast with keyed or rough surfaces and only one coat of plaster is normally required. The slabs can be readily sawn. Plaster slabs are less subjected to shrinkage cracks than concrete slabs.

Wood liners, described on p. 45, may be used effectively in the erection of plaster slab partitions.

*Fixing of Concrete and Plaster Slabs*.—Special precautions should be taken to ensure sound fixing at doors, windows and walls. Two door details are shown at E and F, Fig. 13, and two wall details are given at G and H. Detail E shows the door frame rebated to receive the end of the partition consisting of slabs with square vertical edges, such as those at A, C and D. If the slabs are like B, a small wood fillet may be fixed to the door frame, as shown at F, and this engages in the grooves of the slabs. Alternatively, metal ties with turned-up ends screwed to the post may be built in at some of the bed joints. Certain slabs, such as those composed of coke breeze, pumice, wood-wool, etc., are well spiked to the frames. At G, a chase has been cut in the main wall to receive the ends of the slabs, and at H, two fillets are plugged to the wall, and between them the tongues of the slabs (similar to B) are fitted. See also V, W and X, Fig. 14.

*Reinforced Plaster Partitions*.—There are several methods of forming thin partitions which consist of expanded metal (resembling that at A, Fig. 16, Vol. II) or similar metal reinforcement, covered with plaster. The following is one method : The sheets of expanded metal are wired to ½-in. diameter vertical mild steel rods which are spaced at about 16-in. intervals and securely fixed at their ends to the floor and ceiling. Similar rods, at 20-in. centres, are then wired horizontally to the vertical rods (on the opposite side to the expanded metal) after their ends have been built into the side walls (or screwed to door, etc., frames). One side is plastered, and when this has set a coat of plaster is applied to the other side. These coats are well scratched before setting, and a second coat is then applied to each.

5. Asbestos-cement Partitions.—A portion of a sheet of asbestos-cement (see pp. 120 and 121) which is used in the construction of partitions and flat roofs is

shown at N, Fig. 13. It consists of two flat sheets of asbestos-cement, each approximately $\frac{5}{32}$-in. thick, attached to an inner corrugated sheet (approx. $\frac{1}{8}$-in. thick) of similar material. The sheets are jointed in cement mortar and can be painted or distempered as required. This forms a light, durable, fire-resisting and well insulated partition. It is manufactured by the Turner's Asbestos-Cement Co.

This company also produces flat sheets of asbestos-cement which are given a textured finish in five patterns. The sizes are 8 and 4-ft. by 4-ft. by $\frac{1}{4}$-in. thick. They are butt-jointed and screwed at 12-in. intervals to the studs (16 to 24-in. centres) and noggings (4-ft. centres) of stoothed partitions, or they can be secured to brick, etc., walls to which 2-in. by $\frac{3}{4}$-in. battens are plugged to receive the screws. The sheets can be painted or distempered.

In addition, this company manufactures *wall board*—8-ft. by 4-ft. by $\frac{1}{4}$-in. thick—which is mainly composed of asbestos-cement fibre. These boards are secured to studs, noggings, etc., as described above, the screws (with washers) being spaced at 9-in. at the edges and 12-in. at the intermediate supports.

6. Glass Brick Partitions.—The details at J, K and L, Fig. 13, were prepared from particulars supplied by the manufacturers, J. A. King & Co. Ltd. The section at J shows a portion of a partition composed of 8-in. by 8-in. by $1\frac{1}{2}$-in. solid glass bricks which are grooved on all four edges to permit of slender horizontal and vertical reinforced concrete ribs at the joints. All grooved edges are painted with a light-reflecting paint and then treated with a special bitumastic compound applied hot. This insulation is to permit of expansion and contraction between the glass and concrete. The vertical and horizontal face joints are at least $\frac{5}{8}$-in. thick. Mild steel rods are embedded in the concrete at the joints; the size of this reinforcement varies, but for normal work the horizontal and vertical rods are $\frac{3}{8}$ and $\frac{1}{4}$-in. diameter respectively, and they are wired at the intersections. The bricks are plain on one face with an attractive "flemish" pattern on the other.

The section at L shows a portion of a partition consisting of glass units or lenses with horizontal and vertical reinforced concrete joints. It is a double-glazed parition, each unit being hollow and having two $\frac{1}{2}$-in. thick pieces rebated at all edges. These edges are treated as above. The dimensions of the lenses are 8-in. by 8-in. and 6-in. by 6-in. by $1\frac{3}{4}$-in. when fixed. The joints are only $\frac{1}{8}$-in. thick.

The above are two examples of "Glascrete" construction. Such semi-transparent partitions are being employed for corridors, staircase wells, etc., in contemporary buildings.

Another form of glass brick is shown at X, Fig. 5, Vol. II.

7. Metal Partitions.—Mild steel and bronze are two of several metals which are used in the manufacture of partitions. These may be designed to consist of a series of panels, secured to posts, walls, etc., or the whole of both surfaces may be flush: some of the panels may be prepared for glazing. The panels vary from $1\frac{1}{2}$ to 2-in. thick and may be of 20-gauge mild steel or $\frac{1}{8}$ to $\frac{1}{4}$-in. thick bronze: the thickness of the steel for the posts may be increased to 18-gauge. A sectional plan of a steel post and portions of adjacent panels are shown at O, Fig. 13. The panels are sometimes packed with insulating material (see below). Partitions may also be constructed of bronze or nickel alloys extruded over wood panels or cores; this construction is detailed in Vol. IV.

## SOUND-PROOFING

Sound insulation, or the prevention of sound transmission from one part of a structure to another, is an important subject and one which presents several difficult and complicated problems. As an introduction to the subject it is only possible in this volume to indicate briefly some of the methods employed to improve the sound insulation of some of the types of construction which are included in a second year syllabus, *i.e*, partitions and wood floors.

Sound may be air-borne or it may originate by direct contact with the structure. Speech and music are examples of air-borne sound, and the second or impact type includes noises produced when walking, hammering, or banging doors.

As sound is readily transmitted through cracks, partially filled mortar joints, badly fitting doors and windows, etc., it follows that good insulation cannot be obtained unless sound construction is maintained throughout. For the same reason there should be no gaps between the vertical edges of a cross-partition (such as that shown at B, Fig. 14) and the adjacent main walls or partitions. Nor should there be a space between the head and sill of the partition and the floors.

Sound travels considerable distances along solid walls, and is thereby transmitted from one room to another in a building. It follows, therefore, that division walls or partitions should be isolated from adjacent main walls. This can be effected by using continuous pads (see p. 51) at the edges of the partitions. Insulation at the head and sill of a partition also assists in preventing the transmission of sound from one boundary (such as a floor) to another (see pp. 49 and 51).

In general, the transmission of air-borne sound through walls and floors decreases as their weight increases. A thick, well constructed brick or masonry wall is therefore effective in resisting the transmission of sound. However, the modern tendency is to construct relatively thin walls and light internal partitions, and this has led to an increased application of insulating materials which, because of their porous nature, absorb sound and partially reduce the volume transmitted.

A large number of proprietary materials are now obtainable which are claimed to have high sound-absorbing powers. One of the oldest is *slag wool*, a very light fibrous fireproof material produced by the blowing of steam through molten blast-furnace slag. It may be applied to floors and partitions in a loose condition, when it is called *pugging*, or it can be obtained in quilt or blanket form and in slabs. The quilted kind consists of slag wool which is sewn between specially prepared paper; it is obtained in 3-ft. wide rolls, is $\frac{1}{4}$ to 1-in. thick, and is

applied under floor boards, between studs of partitions, etc. The slabs have a ½-in. thick facing of plaster and a backing of slag wool which is at least 1-in. thick; these are nailed direct to studs, the underside of joists, etc. *Wall boards* form another class of insulating material. These are sheets of wood fibre (shavings) cemented together under pressure, ½ to 1-in. thick, 3 to 4-ft. wide and 6 to 14-ft. long *Celotex*, *Insulite*, *Lloyd Board* and *Tentest* are examples of this material. Wall board composed of asbestos-cement (see pp. 120-121) and supplied in 8-ft. by 8-ft. by ¼-in. sheets is used for sound-proofing; this is an excellent fire-resisting material. As stated on p. 48, insulating material is also sold in quilt or blanket form; *Cabot's Quilt*, consisting of cured eel-grass stitched between strong kraft (brown) paper is one of the best known and is obtainable in 3-ft. wide rolls of ⅜-in. (single-ply), ½-in. (double-ply) and ¾-in. (triple-ply) thickness; this is applied like the quilted form of slag wool. *Hair felt* is another good insulating material, but this is not vermin-proof. An additional type of sound insulator is the wood-wool cement slab described on p. 47. Application of some of these is described below.

*When used normally, these materials only offer partial insulation.* Complete insulation can only be obtained at a cost which is almost prohibitive. As nails provide paths along which sound is conducted, it follows that the nailing of wall boards to joists, studs, battens, etc., should be reduced to a minimum.

A partition formed of two leaves with a cavity between has approximately double the insulation of a non-cavity partition of equal thickness to the combined leaves, *provided the leaves are not connected together by ties*. The wider the cavity the greater the insulation. Whilst wall ties are essential to ensure the stability of external cavity walls (see pp. 40-44, Vol. II), it will be appreciated that sound is transmitted through the ties from one leaf to the other and the good sound-resisting quality of this class of wall is accordingly somewhat reduced.

An independent ceiling and a suspended ceiling (*i.e.*, one supported by light metal hangers fixed to the wood floor joists or in the concrete floor) are effective in preventing the transmission of sound (see L, Fig. 14). Floating floors (*i.e.*, those consisting of light reinforced concrete slabs supported on rubber insulating pads fixed to structural concrete sub-floors) provide further examples of efficient insulating construction.

Rubber, cork and thick carpet coverings (see pp. 40 and 41) are effective in reducing the amount of sound transmitted through floors.

Fig. 14 illustrates typical sound-proof details which incorporate some of the features and materials described above. Certain of these cannot be adopted generally because of their expense. The need for insulating materials will be reduced in a well-planned building in which rooms used as offices (where typewriters are employed), or those accommodating machinery or in which noisy operations are carried out, are arranged in a group and isolated from rooms where quiet conditions are essential. Careful siting of lifts, selection of noiseless fittings (such as flushing cisterns), etc., will also effect a reduction in the amount of insulating material required.

A key plan and section of a portion of a building are shown at A and B, Fig. 14.

The detail at H is typical of the construction which has been employed for many years. The insulating material consists of 2 to 3-in. thickness of slag wool on thin plywood or rough boarding supported on fillets nailed to the joists. The thick arrows show the inadequacy of this treatment, sound being transmitted to adjacent rooms through the thin brick wall, at each joist, and at the gap between the wall and wall joist.

The insulation is rendered more effective if, as shown at J, narrow strips of insulating board are placed between the floor boards and joists. In lieu of the wood fillets, narrow ½-in. thick strips of the insulating material may be nailed to the joists and used to support the light insulating boards.

The detail at K shows an expensive but more efficient method of reducing the transmission of sound. Three insulating layers are used. Quilt, such as that shown at P, may be used instead of the top layer of insulating boards. Plastering applied to the lower layer increases the efficiency. Impact sound is isolated from the wall if, as shown, the skirting is kept clear of the floor and bedded on a rubber, asbestos or felt insulating strip. Alternatively, the bottom edge of the skirting may be bevelled, as indicated at L, in order that contact between it and the floor is reduced to a minimum: in practice this precaution is of no avail if the skirting shrinks and the resulting gap is subsequently covered with a quadrant, etc., fillet to exclude draughts.

The separate ceiling at L, although costly, is most effective. The floor is strutted (although the value of this is overrated) as described in Vol. I, and the insulating layer above it is continued up the wall and secured to grounds or vertical battens plugged to the wall.

A portion of a stoothing (see Fig. 11) is shown at N. Both sides of it are covered with slabs of Thermacoust (see p. 47) which are plastered.

Detail O shows a modified form of stud partition. The discontinuity produced by the staggered studs is partially effective even if the insulating boards shown are not used and the studs are simply lathed and plastered.

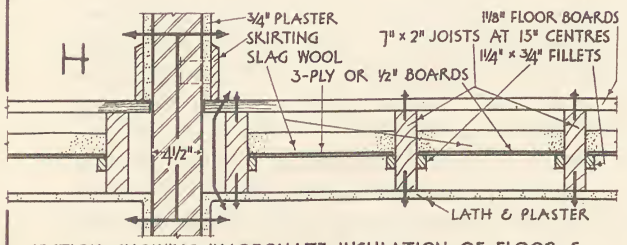
An efficient sound insulated partition is shown at P. The quilt is nailed to the studs. A saving in cost, with little reduction in efficiency, results if two instead of three layers of quilt are applied. Hair felt is also used instead of the quilt, and whilst this is a very good insulating material (provided it is sufficiently thick—preferably 1-in.), felt harbours vermin.

An effective but expensive type of partition, incorporating four layers of insulating material is shown at Q. Floors may be also constructed on this principle. Quilts may be used in lieu of the two inner layers (for partitions) or the three upper layers (for floors) of boards. Another good class of partition is shown at W; *loose* insulating boards may be used instead of the central layers of quilt.

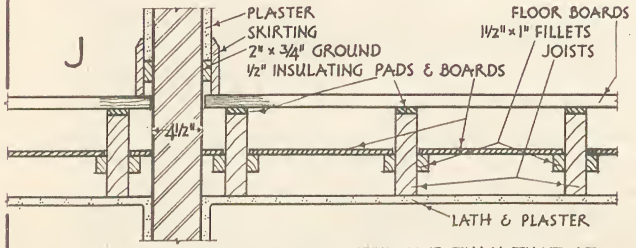
The open grained material (see p. 47) of the thick slabs shown at V, together with the wide cavity (which must not be bridged by metal ties) produces an efficient insulated partition.

Typical details at the head and sill of stud partitions are shown at R, S, T

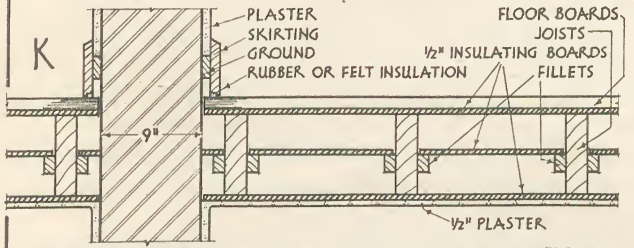
# SOUND-PROOF DETAILS



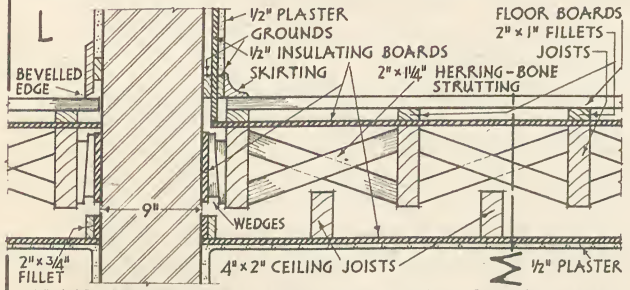

SECTION SHOWING INADEQUATE INSULATION OF FLOOR & WALL. SOUND PATHS ARE INDICATED BY THICK ARROWS




THIS FLOOR INSULATION IS MORE EFFECTIVE THAN THAT AT "H", BUT TRANSMISSION OF SOUND THROUGH WALL NOT REDUCED

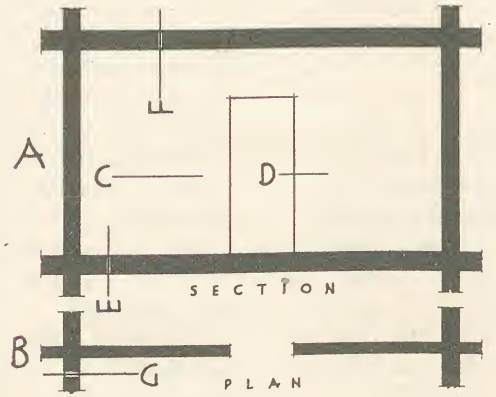



INCREASED EFFICIENCY RESULTS BECAUSE OF THE THREE FLOOR INSULATING LAYERS, THE THICKER WALL & THE SKIRTING INSULATION

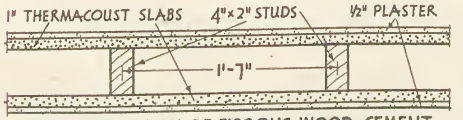



SOUND TRANSMISSION IS EFFECTIVELY REDUCED BECAUSE OF THE INDEPENDENT CEILING & THE INSULATION OF THE FLOOR & WALL

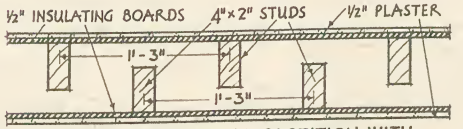
ALTERNATIVE DETAILS AT "G"



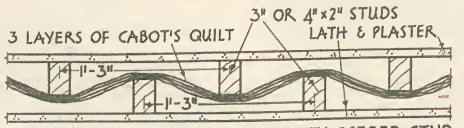

KEY PLAN & SECTION OF PART OF BUILDING



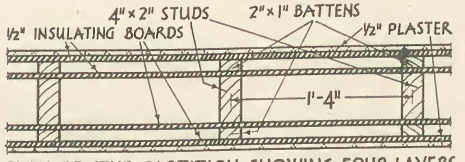

PLAN OF PARTITION OF FIBROUS WOOD CEMENT SLABS, WITH PLASTER FINISH, FIXED TO WOOD STUDS




PLAN OF STAGGERED STUD PARTITION WITH PLASTER FINISHED INSULATING BOARDS

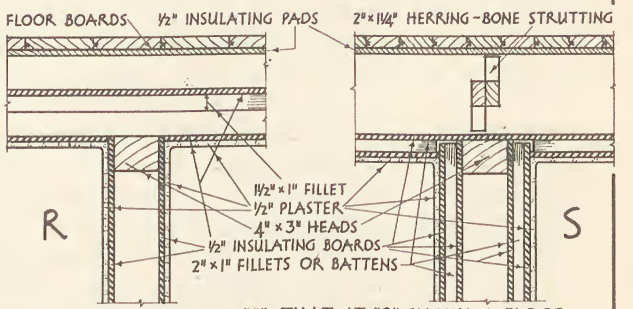



PLAN OF LATHED & PLASTERED STAGGERED STUD PARTITION WITH INTERMEDIATE QUILT HANGING

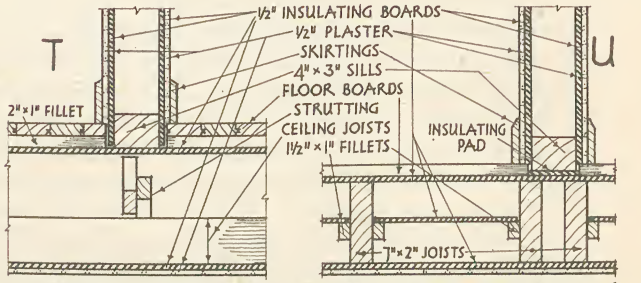



PLAN OF STUD PARTITION SHOWING FOUR LAYERS OF INSULATING BOARDS & ½" PLASTER FINISH

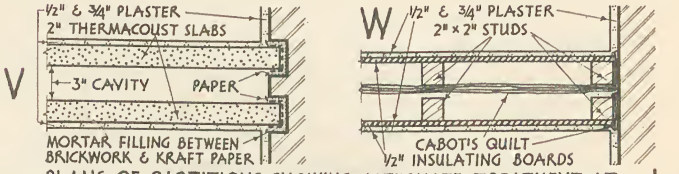
ALTERNATE DETAILS AT "C"



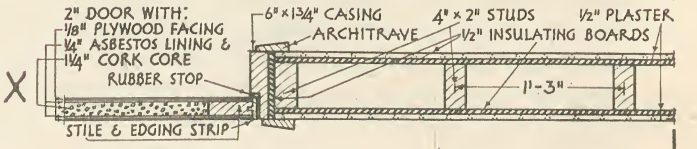

ALTERNATE DETAILS AT "F". THAT AT "R" SHOWS A FLOOR SIMILAR TO "J", WITH CEILING INSULATING BOARDS, & HEAD OF PARTITION AT "X". THAT AT "S" SHOWS HEAD OF PARTITION "Q" & CEILING INSULATING BOARDS SECURED TO FILLETS AT 15" CENTRES




ALTERNATE DETAILS AT "E". THAT AT "T" SHOWS SECTION "M" OF FLOOR "L" & SILL OF PARTITION "X". THE PARTITION AT "U" IS SHOWN PARALLEL TO THE JOISTS & INSULATED FROM THE FLOOR




PLANS OF PARTITIONS SHOWING ALTERNATE TREATMENT AT JUNCTIONS. THAT AT "V" SHOWS THE LEAVES SET IN CHASES & THE JUNCTION AT "W" IS TIGHTLY CAULKED BY QUILT




DETAIL "D"

SCALE FOR DETAILS FEET

FIGURE 14

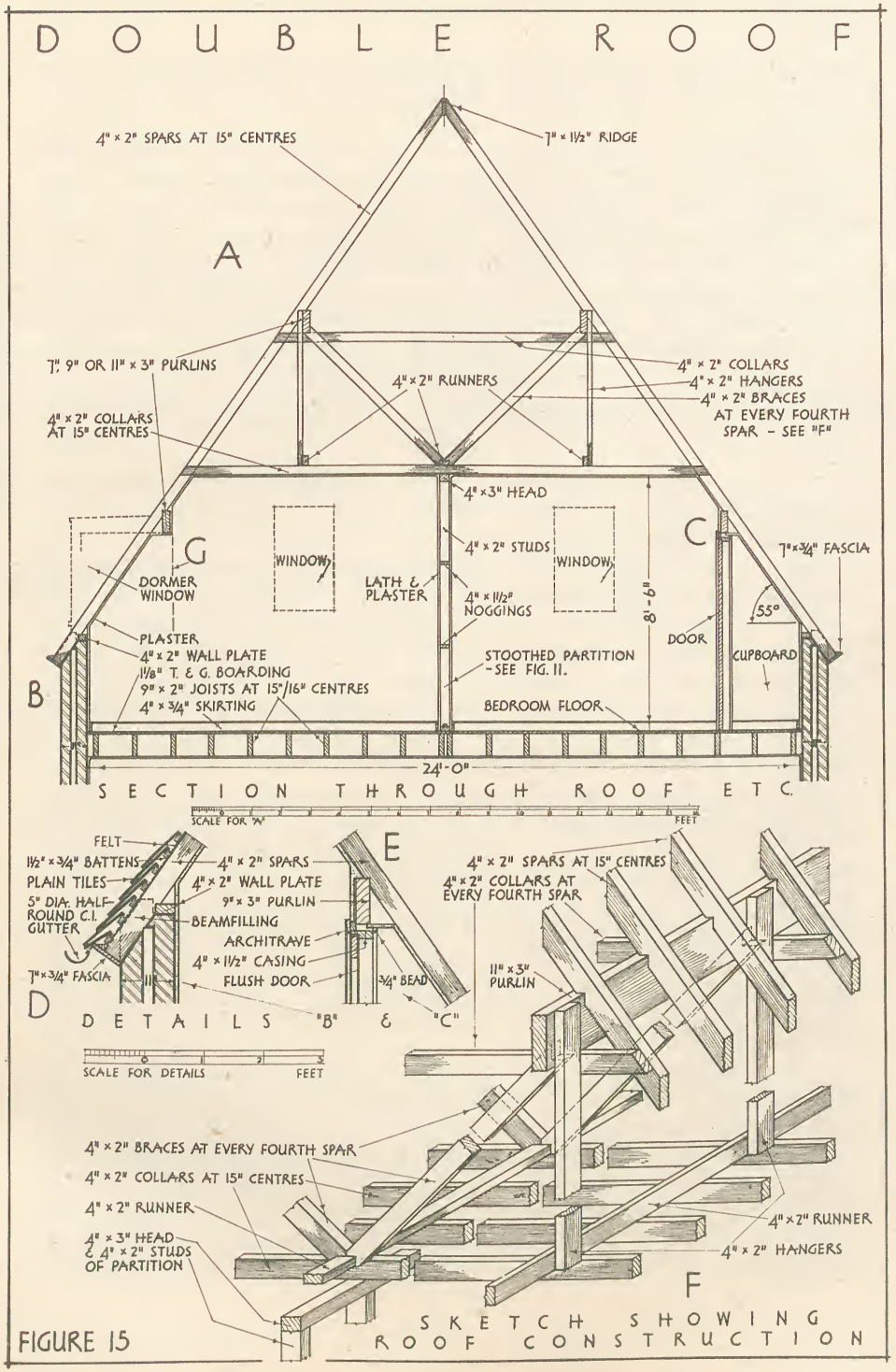



FIGURE 15



and U. The precautions which are taken to isolate the partitions from the floors should be noted; thus, the insulating pad at U is wider than the wood sill of the partition, and this prevents contact between the floor boards and the sill.

Two methods of providing discontinuity are shown at V and W. Each leaf of the former partition is let into a chase in the main wall. Whilst this increases the stability of the partition, a rigid connection is avoided because of the presence of the brown paper, and thus cracking of the partition is prevented if any unequal movement between it and the wall occurs. Alternatively, the chases may be packed with insulated quilt to prevent the transmission of sound. The caulking of the edges of the partitions shown at W is also effective in preventing the formation of sound paths.

*As dry rot has occurred when sheets of wood fibrous insulating material have not been adequately ventilated—such as the inner boards at Q and in the class of partition at W—care should be taken to ensure that only those boards not liable to decomposition are used in unventilated positions. Such defects are not likely to occur if sheets composed of asbestos, slag wool or similar inert material are used in unventilated cavities.*

Doors are vulnerable to the transmission of sound from one room to another. They should be tight-fitting and as thick as possible One type of door is shown at X. This is of the flush type (see Fig. 25) and consists of a skeleton wood frame (stiles and rails) covered at each side with a sheet of asbestos or similar insulating material, faced with plywood; if desired, the latter may be dispensed with and thicker sheets of asbestos (subsequently painted) employed. A good insulator, such as granulated cork, is packed to form a core. A sound-proof door in which granulated cork is employed is illustrated at E and J, Fig. 25. Draught strips, rubber or felt, are shown fixed at the rebate of the casing. A draught excluder fixed at the bottom of the door will increase its efficiency. Any space between the casing and the partition should be filled with an insulating strip, as shown, or be tightly caulked with quilt.

Windows present a difficulty, and it is not possible to render them capable of totally excluding noise from heavy street traffic, etc. They should be close fitting, and therefore casements are more effective than the double hung sashed type. Double glazing is recommended and thick glass (such as ¼-in. thick plate) should be used. Thus the window will consist of two solid frames, each glazed, with a 2 to 6-in. cavity between. The outer frame should be insulated from the inner, quilt pads or insulating strips being used between. These windows are preferably of the fixed type; when such are employed, artificial ventilation must be provided for the rooms concerned.

## ROOFS

Single, double and framed roofs are described on pp. 68-81, Vol. I.

DOUBLE ROOFS.—Two examples of a double or purlin roof, not previously considered, are illustrated here in Figs. 15 and 16.

That detailed in Fig. 15 is often employed for roofs of houses in which attics

for bedrooms or other purposes are provided. It is steeply pitched at an angle (55°) which gives a very satisfactory appearance, and is especially suitable if the covering is plain tiles (see D and Fig. 41); little difficulty is experienced in obtaining the necessary height of rooms when the roof has such a pitch. It consists of spars, supported by two sets of purlins, and lower or principal collars. The spars and these collars are spaced at 15-in centres. There is, in addition, a second set of collars supporting the upper pair of purlins; these collars are provided at every third, fourth or fifth pair of spars, to which they are securely nailed and preferably dovetail halved jointed (see p. 73, Vol. I). The portion of roof between the collars is triangulated by braces or struts, birdsmouthed to the purlins, and a central runner nailed to the ceiling joists and placed immediately over a stout stoothed partition (see Fig. 11). Hangers and runners are provided as intermediate supports to the ceiling (see p. 72, Vol. I), the former being spiked to the purlins and runners. Alternatively, the hangers may be placed with their edges adjacent to and notched over the purlins and runners, and nailed to the spars, etc. It will be noted that, like the upper collars, the braces and hangers are spaced at every third, fourth or fifth spar apart.

To ensure complete rigidity, it is advisable to provide an adequate support for the partition in the form of double floor joists, as shown at A, or a single joist of sufficient thickness.

The sketch at F shows more clearly much of the construction described above.

The section at A shows two alternative methods of treating the sides of the room. The shape of such a room is improved if, as illustrated on the right, a studded partition is fixed along the side below the purlin. The space between the outer wall, roof and partition may be utilized for storage. The door is detailed at E. *Ashlaring* is the term applied when studding is used for this purpose, especially when the floor is at the level of the eaves. A dormer window [1] is shown in broken outline on the left. If required, studding may also be employed here below the lower purlin, returned studded ends being provided at the window; the plastered face of the side studding would then be as indicated by the partly broken line at G.

It is explained in Vol. I that it is usual to limit the unsupported length of purlins to 16-ft. and that roof trusses are provided when this span is exceeded. Whilst this conforms to the general practice, it is possible to dispense with roof trusses, provided some suitable alternative construction is adopted. The double roof shown at A, Fig. 16, is an example of a structure of moderate span in which roof trusses are not employed, although the distance between the cross walls is assumed to be 28-ft. This shows two alternative means of support for the purlins, *i.e.*, a *trussed purlin* at C and a mild steel beam with a partition at D.

As shown at A, the central portion of the roof is so constructed as to provide bedroom, etc., accommodation which is lit by means of windows in the gable walls. Collars are placed at a sufficient height to give adequate headroom, and the partitions and ceiling are either lathed and plastered or covered with wall board (as shown), match-boarding, plywood, etc. If this space is only to be used for storage, the collars may be lowered to the position shown by broken lines at Y.

An elevation of a little more than half of the trussed purlin is shown at B. This is of lattice construction consisting of two longitudinal members called *booms*, compression members or braces or struts, and tension members in the form of steel or wrought iron rods. The top boom is, in effect, a purlin, placed vertically, which supports the spars birdsmouthed to it. The lower boom supports the ceiling, floor joists and partition (see V). In addition, the trussed purlin supports part of the load from the lower purlin, which is transmitted to it by bearers placed at approximately 7-ft. 2-in. centres (see B, C, Q and U). These bearers are nailed to the spars at one end (see U) and to the braces at the other (see Q). The structure is triangulated hereabouts by 4-in. by 2-in. struts nailed to the spars (see U) and oblique mortised and tenoned to the lower boom (see V).

The studs provided at the trussed purlin are indicated at B by broken lines in order not to confuse the detail; these are fixed as explained on pp. 42 and 43.

Details of the trussed purlin are shown at P, Q, R, S, T, U, V and X. Some of them are very similar to those described in connection with trussed partitions (pp. 43 and 45), the centre-line principle being observed in setting out the members.

The detail at P shows the structure to be supported on a pad stone at each end, and the foot of the brace is bridle jointed and well spiked (or bolted) to the lower boom. The detail at Q shows the bearer supported by a cleat notched to receive it and nailed to the side of the brace and purlin; a triangular block, nailed to the back of the brace and to the bearer, assists in making a rigid connection. The opposite end of the bearer is spiked to the side of the spar (see U); a dovetail halved joint (see Z, Fig. 36, Vol. I) may be used. The upper end of each end brace is tenoned to the purlin (see R), and a block, well spiked to the purlin, increases the abutment. Details at the ends of the middle braces are shown at S and T. Details at the ends of the rods are shown at R, S, T and X; the rods are provided with nuts and washers at their lower ends (see S and X), and details at R and T show the heads and washers. The rods are finally tightened after the trussed purlin has been erected and the roof covering fixed. The detail at V shows the ends of the floor joists dovetail housed (see M, Fig. 34, Vol. I) to the lower boom, and the ceiling joists are notched over a fillet well spiked to the boom.

The alternative support for the purlins is shown at D and detailed at W. The latter shows a section of a mild steel beam, which has a bearing at each end on a pad stone built into the cross wall, and to which the 4-in. by 3-in. sill of the stud partition is secured by $\frac{1}{2}$-in. diameter bolts staggered at 2 to 3-ft. centres. Cradling (see pp. 34 and 36) is fixed for the plasterers' laths. The ends of the floor and ceiling joists have a 4-in. bearing on the sill to which the lower ends of the 4-in. by 2-in. struts are birdsmouthed. The top ends of the struts are secured to the spars, as are also the 4-in. by 2-in. bearers; the construction is

[1] Dormer windows are detailed in Vol. IV.

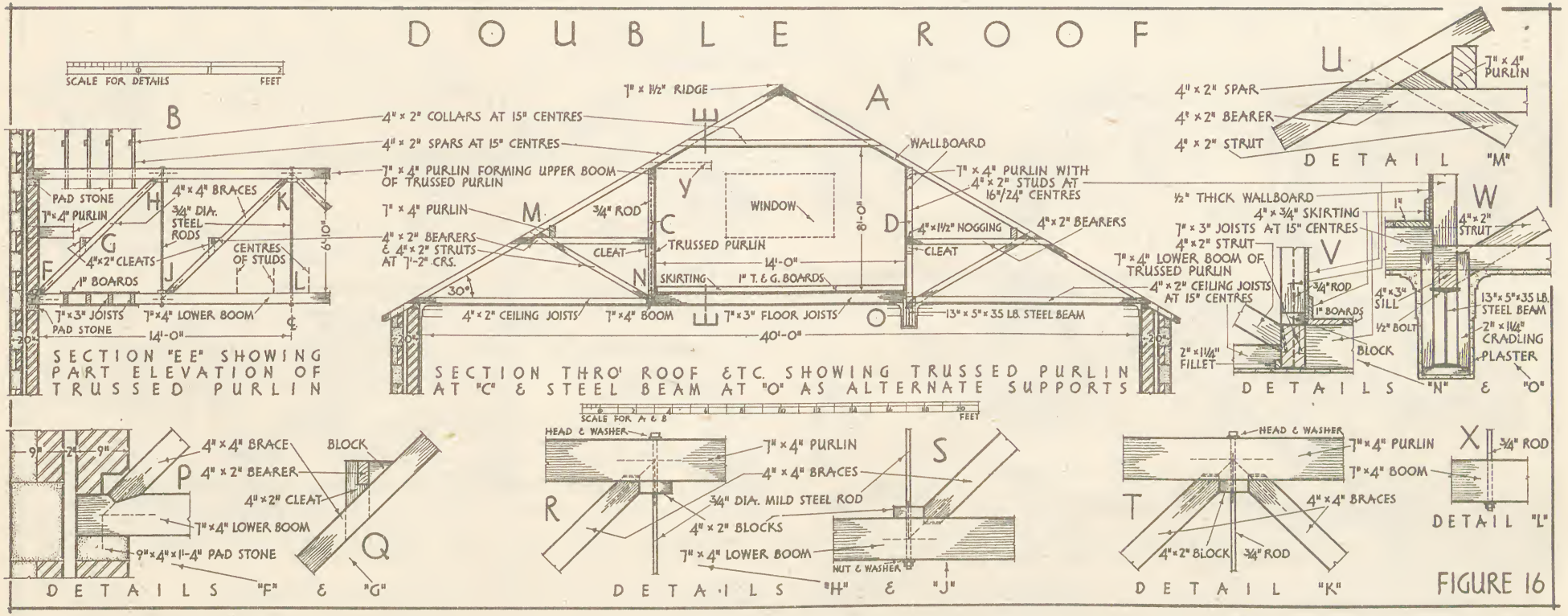



FIGURE 16

therefore similar to that shown at U. The opposite ends of the bearers are supported on cleats fixed to the studs (see D). These struts and bearers are provided at every third, fourth or fifth spar.

LAMINATED WOOD TRUSSES.—This form of truss is so called as its members are built up of thin timbers. *It is only employed when the covering material is light in weight*, such as corrugated sheets or large tiles of asbestos-cement (see pp. 122 and 123) or corrugated iron sheets. Roof construction of this type is most efficient and economical. These trusses are often used for farm buildings (stables, byres, sheds, etc.) and huts, and also for so-called semi-permanent buildings, including certain schools.

Two examples are illustrated in Fig. 17. That at A is suitable for a span preferably not exceeding 20-ft. Details are given at B, C, D and E. These show light scantlings which are simply *securely spiked* together at the joints. Each principal rafter consists of two 5-in. by 1¼-in. timbers and the main tie comprises two lengths of 6-in. by 1¼-in. stuff. The struts and secondary ties are single members and pass between each of these double members. The joint at the apex is made rigid by nailing a 1-in. thick board at each side (see C). This may be longer, as shown at L, and 1-in. boarding nailed at both sides at the feet in addition to either 2-in. thick middle boards or short packing pieces (see B) increase the rigidity of the structure. The spacing of the purlins depends upon the size of the covering, which for abestos-cement sheets is usually 3-ft. centres. Provision must be made to prevent the purlins from tilting. Hence the upper ends of the struts and subsidiary ties are continued as shown at C and D (the purlins being omitted from the former for the sake of clarity); cleats are provided as side supports of the intermediate purlins, preferably as shown at J or, alternatively, as at K.

Mild steel plates, as shown at E, provide good bearings for the trusses.

A detail at the eaves is shown at E. A deep fascia, plugged to the wall and nailed to the wall plate, etc., is adopted to cover the ends of the main ties. As the external wall is only 9-in. thick, and in order to prevent dampness, the external face is covered with two coats of cement and sand mixture or rough-casted[1] as indicated. An enlarged eaves detail is provided at K, Fig. 47.

It is emphasized that the rigidity of the structure can only be satisfactory provided the members are well spiked at all joints.

These trusses are spaced at from 7 to 10-ft. apart, depending upon the weight

[1] Plastering is specified in Vol. IV.

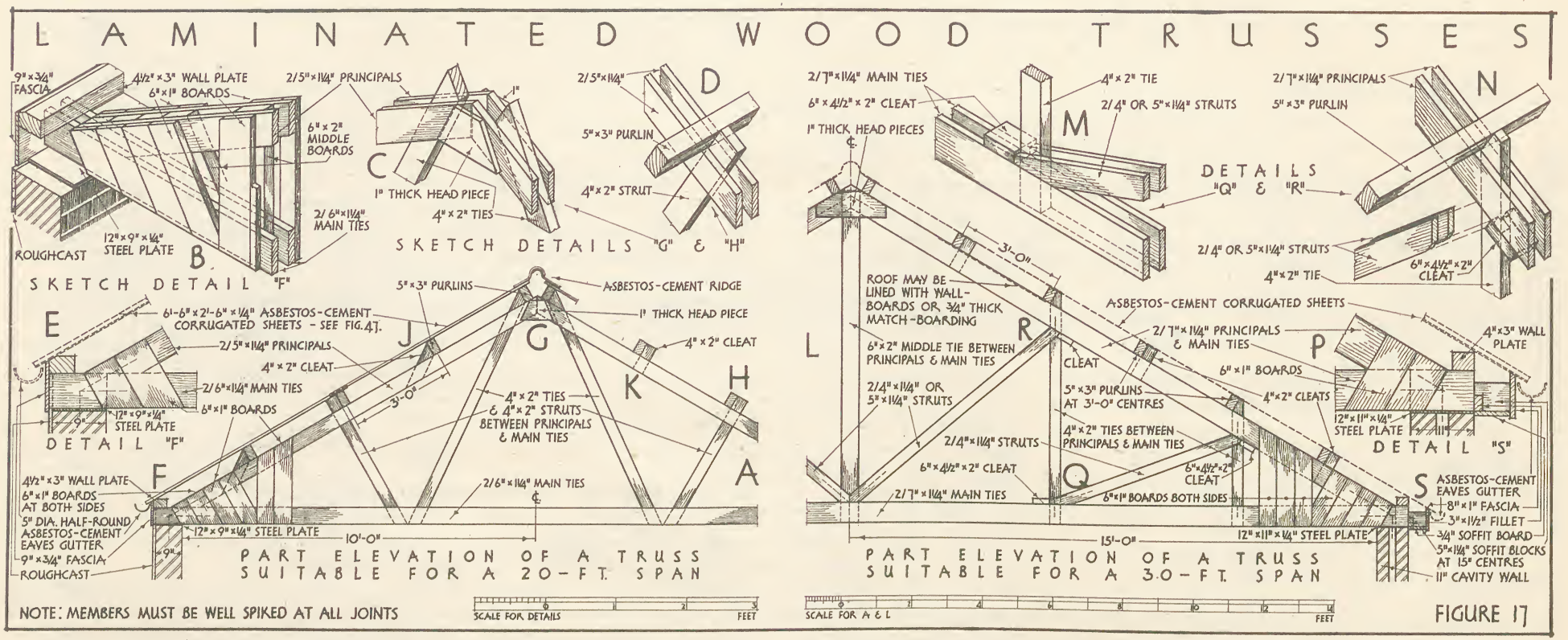



FIGURE 17

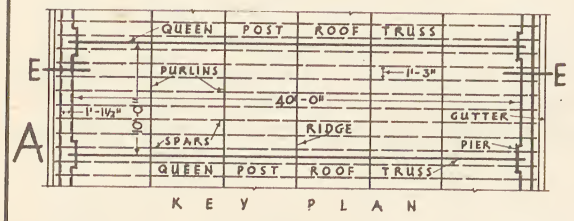
of the covering material, span of roof, size of members, quality of the timber, etc. *No intervening spars are required when large sheets, such as those stated on p. 53, are used as a covering material.* A lining to the roof may be provided, if required. Thus, asbestos-cement plain sheets, wall boards, match-boarding, etc., may be nailed to the underside of the purlins, and such may be fixed to vertical battens plugged to the walls. If a plastered ceiling is necessary, ceiling joists must be provided to span the building and be supported by the walls at truss level.

A part elevation of this type of truss, but for a larger span, is shown at L and detailed at M, N and P. The construction is similar to that described on p. 53. Cleats or blocks are shown at the heads of all struts and the feet of the shorter ones, but these are often omitted to minimize labour and therefore cost. In order to provide a firm fixing for the 1-in. outer boards nailed at the feet, either 2-in. thick middle boards or packing pieces must be nailed between the principals and main ties. Thorough spiking is essential. The eaves is shown projecting beyond an 11-in. cavity wall.

QUEEN POST ROOF.—The king post roof truss, illustrated in Fig. 40, Vol. I, is suitable for spans not exceeding 30-ft. For greater spans up to 45-ft., and if timber is to be employed, the queen post roof truss is the most suitable type. Few of these are now used, as mild steel roof trusses are generally preferred (see pp. 121-128, Vol. II).

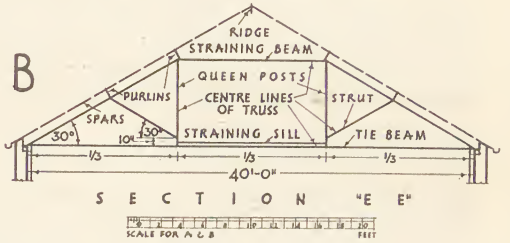
The queen post roof truss is illustrated in Fig. 18. The key plan at A shows these at 10-ft. centres, the walls being strengthened by piers to receive them. A part elevation is shown at C (the end of the tie beam being shown by full lines) and the outline indicating the setting out is given at B. A comparison between this truss and that of the king post shows that it has two posts, called *queen posts*, and two additional horizontal members, *i.e.*, a *straining beam* between the heads of the posts and a *straining sill* between their feet; the truss also supports an additional pair of purlins. The posts support the tie beam at one-third points (see B). Many of the details are the same as those of the king post truss, and need not be repeated here. Except for the upper purlin, the centre-line principle is adopted in setting out the truss; as shown at F, this purlin is above the centre in order to avoid awkward cutting at the head of the queen post.

# QUEEN POST ROOF



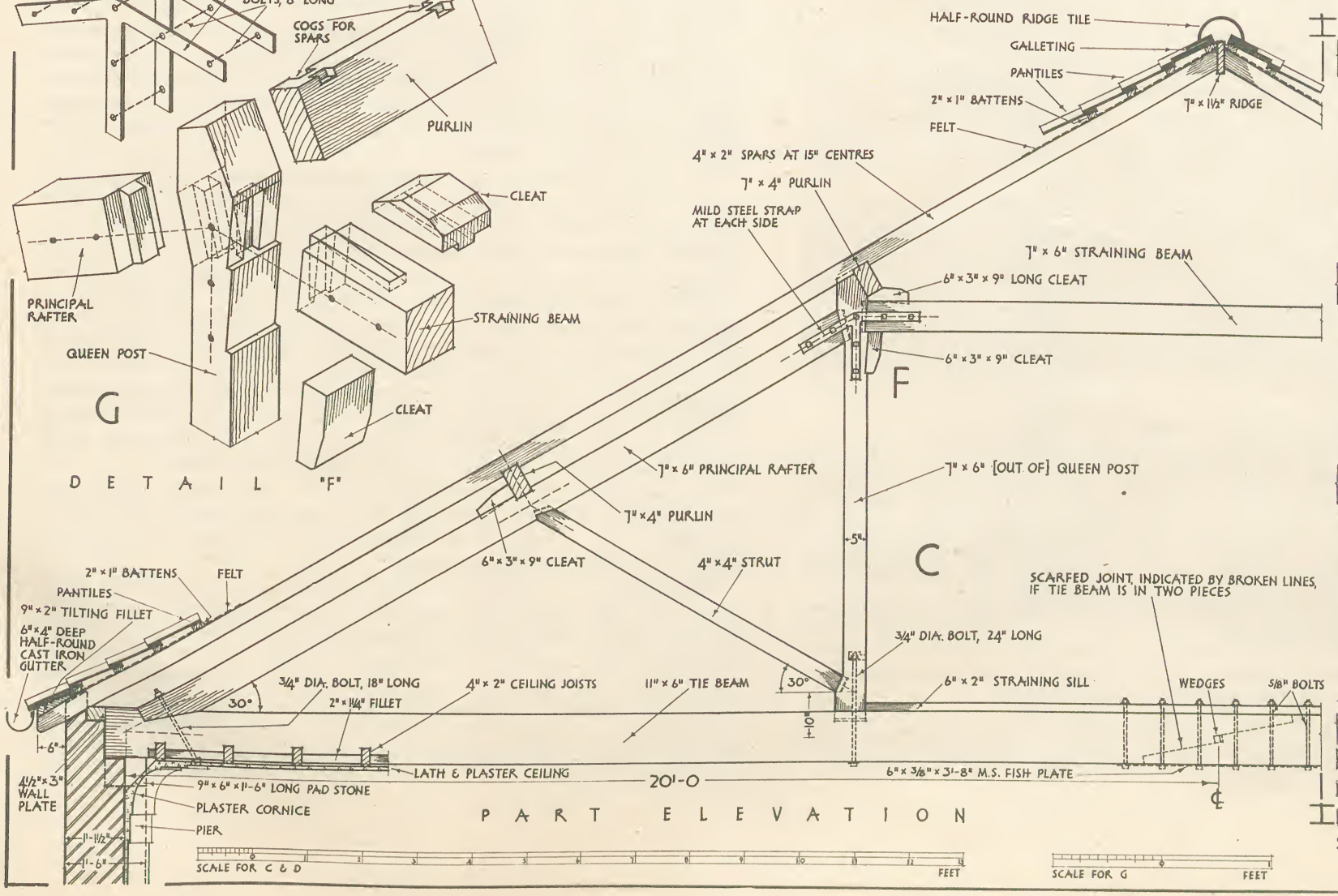

NOTE: MILD STEEL ROOF TRUSSES – SEE FIG. 50, VOL. 2 – HAVE LARGELY SUPERSEDED THOSE OF TIMBER CONSTRUCTION

SEE FIGURE 40, VOLUME ONE FOR DETAILS OF THE JOINTS AT THE STRUTS, FEET OF PRINCIPAL RAFTERS, ETC.








HALF-ROUND RIDGE TILE
GALLETING
PANTILES
2" × 1" BATTENS
FELT
7" × 1½" RIDGE
4" × 2" SPARS AT 15" CENTRES
7" × 4" PURLIN
MILD STEEL STRAP AT EACH SIDE
7" × 6" STRAINING BEAM
6" × 3" × 9" LONG CLEAT
6" × 3" × 9" CLEAT
F
7" × 6" PRINCIPAL RAFTER
7" × 6" [OUT OF] QUEEN POST
7" × 4" PURLIN
6" × 3" × 9" CLEAT
4" × 4" STRUT
C
SCARFED JOINT, INDICATED BY BROKEN LINES, IF TIE BEAM IS IN TWO PIECES
2" × 1" BATTENS
FELT
PANTILES
9" × 2" TILTING FILLET
6" × 4" DEEP HALF-ROUND CAST IRON GUTTER
¾" DIA. BOLT, 24" LONG
¾" DIA. BOLT, 18" LONG
4" × 2" CEILING JOISTS
11" × 6" TIE BEAM
30°
6" × 2" STRAINING SILL
WEDGES
⅝" BOLTS
2" × 1¼" FILLET
LATH & PLASTER CEILING
20'-0
6" × ⅜" × 3'-8" M.S. FISH PLATE
9" × 6" × 1'-6" LONG PAD STONE
PLASTER CORNICE
PIER
4½" × 3" WALL PLATE
PART ELEVATION
SCALE FOR C & D
FEET
SCALE FOR G
FEET

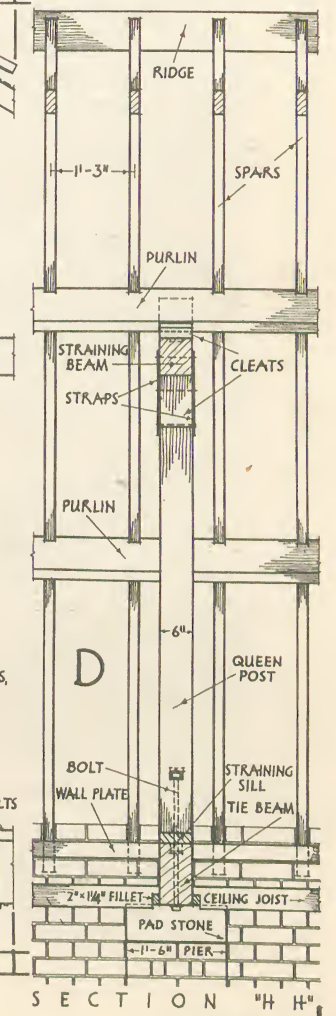



FIGURE 18

An enlarged sketch detail of the connections at F is shown at G. The straining beam, which is in compression, as it resists the thrusts from the principal rafters, is bevel housed and tenoned to the queen post. An increased bearing is provided by the cleat which is bevel housed to the queen post. The principal rafter is tenoned to the post, which, like the king post, is shaped to provide a bevelled shoulder and a sound abutment. The strength of the joint is increased by a ¼-in. thick 3-way steel strap at each side, secured by bolts. The head of the post is bevelled to suit the purlin, and a cleat provides a satisfactory bearing for the latter.

The straining sill, which assists in counteracting the thrust from the struts, should be fitted tightly between the feet of the posts and nailed to the tie beam.

It is usual to form the tie beam of two pieces because of the difficulty and expense of obtaining single pieces of such large size. A suitable lapped joint between two pieces is shown by broken lines at C. It is a splayed scarf joint with folding wedges and a mild steel fish plate. The length of the joint must be at least three times the depth of the beam. This is a better form of scarfed joint for this purpose than that shown at R, Fig. 37, Vol. I, as the folding wedges when driven in draw the two pieces tightly together.

A section through the roof is shown at D. Small fillets are nailed to the tie beam to support the ceiling joists. The total weight of the plastered ceiling, including joists, is approximately 2-tons, and if a ceiling is not required, the thickness of the members of the truss can be reduced to 4-in. The space between the queen posts is sometimes used to provide storage, etc., accommodation, the joists forming the floor being supported on the tie beams; allowance for the additional weight of the floor, together with the superimposed load (that supported by the floor) must, of course, be made when deciding upon the scantlings of the truss members.

The tiling details are drawn to a larger scale in Fig. 44.

If subjected to high wind pressure and non-uniform loading of the floor (if provided), this type of truss is liable to become distorted because of the non-triangulated portion bounded by the posts, tie beam and straining beam. Deformation is not likely to occur if the joints are soundly constructed. Additional rigidity can be obtained by triangulating this rectangular portion with two diagonal braces, each extending from the foot of the queen post to the opposite corner formed by the straining beam and queen post.

Mild steel roof trusses, suitable for relatively small spans, are illustrated in Figs. 47, 48, 49 and 50, Vol. II.

## TEMPORARY TIMBERING

The use of timbers for the temporary support of trenches and newly constructed arches is dealt with in Vol. I. The following is an extended description of these two forms of construction.

### TIMBERING OF EXCAVATIONS

Whilst this work is not carried out by carpenters, but by those actually engaged on the digging operations, it is convenient to include it here.

Reference should be made to the typical methods of supporting the sides of shallow trenches described on pp. 82 and 83, Vol. I. The various members there mentioned are also used for deep trenches. These include poling boards, walings, struts and sheeting.

The object of the timbering is, of course, to retain the sides of the excavations and thereby (*a*) provide safe conditions for the men engaged upon the digging operations and the subsequent construction of the drains, foundations, walls, etc., and (*b*) prevent damage occurring to adjacent buildings, road surfaces, and drain, gas, water, etc., pipes.

Several methods of timbering employed for comparatively deep trenches are illustrated in Fig. 19. *These are typical only*. The sizes and disposition of the members are subject to considerable variation, according to the nature of the soil, the earth pressure to be resisted, the time occupied between the commencement of the work and the filling in of the excavations, and the stock of timber which is readily available.

As mentioned in Vol. I, there are many kinds of soils, varying from a sound rock in a cutting through which no timbering is required, to silt or mud in which excavations can only be made with difficulty and after close boarding or the equivalent has been provided. Extreme conditions may exist on one site, and therefore a common system of timbering cannot always be adopted throughout.

Earth pressures are also variable. Thus, a dense clay when subjected to heavy rain may expand and exert a considerable pressure on the struts in a newly timbered excavation, but the same soil may shrink in dry weather to such an extent as to cause the timbering to collapse if precautions—such as the tightening of the struts—are not taken. In most soils the pressure does not increase with the depth of the excavation, and therefore in a deep cutting in soil which is the same throughout, the size and spacing of the timbers at the bottom need only be the same as those provided near the surface.

Trenches which are to remain open for a long time usually require more poling boards and larger walings and struts than those cuttings which are to be refilled quickly. The less the distance apart of the struts, the smaller the sizes of the walings and struts required.

The timbers are roughly sawn, and the following are commonly used: Spruce for poling boards and runners (see p. 58); pitch pine or Douglas fir for large squared members such as walings, struts and props; larch for circular struts and props; and beech or pitch pine for wedges.

Trenches in Moderately Firm Ground (see A, B and C, Fig. 19).—The section at B is that of a trench in which a drain is to be constructed and shows approximately 4-ft. depth of loamy soil or dry chalk, which does not require close or heavy timbering, overlying a bed of loose gravel which needs to be timbered more closely.

The upper 7-in. by 1½-in. poling boards, placed at 1-ft. 6-in. centres (see C) are held in position by a single waling along the centre, and they are accordingly known as *middling boards*. Struts are placed between the walings at a minimum distance of 6-ft. so as not to unduly impede the digging operations.

The lower set also consists of middling boards. These are wider than those in the upper "setting," although the narrow boards may also be employed, provided the distance between them is that considered to be necessary, *i.e.*, 6-in.

A pair of walings, together with their struts, is known as a *frame*, and it is advisable to support these by vertical props or *puncheons*, wedged between the walings at or near the ends of the struts. Puncheons are necessary, especially in deep excavations where the ground is uncertain, to prevent the walings from dropping. They are often dispensed with when the ground is reasonably firm and the trench is to be left open for only a short while. In this example, each puncheon is placed between the walings and continued with a short piece supported on a *sole plate*, partially embedded in the ground, to distribute the weight. As shown more clearly at D, a pair of *driving* wedges (or a pair of folding wedges as used for centering, see Fig. 20) are used to tighten the lower puncheon, and the upper puncheon is brought tightly up to the top waling by driving wedges between its foot and the lower waling (see A).

A *platform* or *staging*, necessary to receive the soil as the excavation proceeds, is shown at B, C (by broken lines) and a portion at A. This necessary provision is referred to in the next column.

The following is the usual procedure adopted in fixing this type of timbering : The ground is excavated to a sufficient depth to allow the top setting to be fixed. A waling is placed along each side in the correct relative position and supported by temporary puncheons. A pair of middling boards is placed between the walings and the sides of the excavation at approximately 6-ft. centres. Small wood packing pieces are placed between the boards and the walings, and these pieces are afterwards replaced by small wedges called *pages*. A strut is fitted between the walings opposite each pair of boards and tightened by driving in wedges at *one side only*. The rest of the polings are now placed in position between the walings and soil and forced tightly against the sides of the excavation by driving down pages between the boards and walings. The excavation is continued to the required depth and timbered as described above. If the tops of the middling boards of the lower setting are level with the feet of those above, all of the former can be placed in position by forcing their lower ends into the ground and nailing them at the top to the boards above. The walings and struts of the bottom setting are then placed and wedged, and the puncheons are finally fitted and wedged.

The struts should be tightly wedged, although care should be taken not to disturb the sides of the excavation by overdriving the wedges.

The timbering should be occasionally examined and any slack wedges and pages, due to the shrinkage of the soil, etc., tightened. If the struts show signs of bending, due to the extra pressure caused by the expansion of the soil during very wet weather, the wedges should be eased as required.

The sketch at A shows more clearly the timber details. It also illustrates a portion of the drain, embedded upon concrete, which is laid to the required fall in a narrow and shallow trench excavated at the bottom of the main trench (see p. 75 and Fig. 29, Vol. II).

Middling boards are only suitable for trenches dug in comparatively good ground.

TRENCHES IN DOUBTFUL GROUND (see F, G and H).—These illustrate the use of poling boards, called *tucking boards*, which are used for excavations in loose soil, such as made-up ground (soil, etc. which has been tipped into hollows in the ground and levelled over) and soft clay. The section shows a relatively wide trench required for a sewer, and three settings of boards are employed. The boards in each setting are secured at both ends between walings. Each of the middle and lower walings has a continuous wood fillet nailed to it level with its upper edge (see V) ; this is called a *liner*, and its thickness equals that of the boards. The upper boards are "toed" into the soil behind the liners of the middle walings until their feet are approximately level with the underside of the walings. Pages are driven down at the top between the boards and walings and, as required, at the bottom between the liners and boards (see H and V). The boards forming the second setting are "tucked" into position (hence their name) by placing them diagonally and fitting their heads between the waling and the feet of the upper boards, and forcing their bottom ends into the soil behind the liner nailed to the lower waling until they assume a vertical position. Pages are inserted to fasten any loose boards. The boards in the bottom setting are placed and held in a similar manner. The walings are supported by puncheons and the struts are tightened by wedges, as described in the preceding column.

To facilitate the handling and fixing of heavy struts, it is customary to nail short strips of boards at their ends (see E, G and H). These are called *lips* or *lipping blocks*. The struts are placed in position with their lips supported on the walings, and wedges are then driven in horizontally between one end of each strut and the waling. Temporary props may be used in lieu of lips.

Two platforms are shown in the section at G. There is a limit to which men can conveniently throw the excavated soil. This limit is considered to be 5-ft. Hence platforms or stages to receive the soil must be provided at approximately 5-ft. vertical intervals, and the top stage should preferably be not more than 4-ft. below the surface in order that the earth deposited on it may be thrown well away from the sides of the trench. Platforms consist of stout planks placed upon struts which are either cleated (see L) or propped. An edging to a platform, as shown, assists in retaining the heap of deposited material, but this is often omitted. They are usually arranged on alternate sides (see G and L) and staggered, as shown by broken lines at F and M. The soil excavated from the lower level of a deep trench is therefore shovelled from one platform to another until finally

disposed of at the ground level. Thus, at F and G the earth would be thrown on to the bottom platform (known as the *first lift* or *throw*), a man working on this platform shovels the material on to the top platform (or *second lift*) from which it is thrown out of the trench. In large excavations the soil is often shovelled into receptacles which are lifted by a crane and deposited where required on the site or emptied direct into a lorry in which it is conveyed to the nearest convenient tip.

TRENCHES IN LOOSE AND/OR WATERLOGGED SOIL.—Great care must be exercised to prevent the caving in of trenches formed in bad ground. The soils which come under this class are soft plastic clay, certain conditions of sand, silt, wet chalk and peat. Damp sand is not difficult, but it can be most troublesome if it is in a very wet condition or is fine and dry. The latter is not easy to confine, as it readily " flows " through small spaces between timbers ; the escape of such loose material may cause settlement and the total collapse of the timbering. Such bad ground is retained by either (*a*) horizontal sheeting or (*b*) vertical timbers called *runners*.

(a) *Sheeting* (see L and M).—The section at L shows a stratum of wet sand between two beds of moderately firm ground. This, therefore, shows the application of a composite system of timbering.

The lower portion is timbered with middling boards, as described on p. 57, and the upper setting may also consist of these boards. As an alternative, however, poling boards with two frames instead of one have been shown as the support in the upper setting.

The sheeting is fixed in easy stages, as described on p. 83, Vol. I. Any small openings between the boards, as at T, should be *stemmed* by the packing of wads of grass or straw between the timbers. Whilst this does not stop the flow of water, it does prevent the infiltration of particles of sand. Puncheons should be used, as indicated. The sides of the trench are shown battered, a practice which is sometimes adopted if there is a tendency for the soil to shrink. Whilst this does not prevent the struts from working loose, it does tend to prevent the collapse of the timbering. Careful supervision is necessary, and the strut wedges must be adjusted as required.

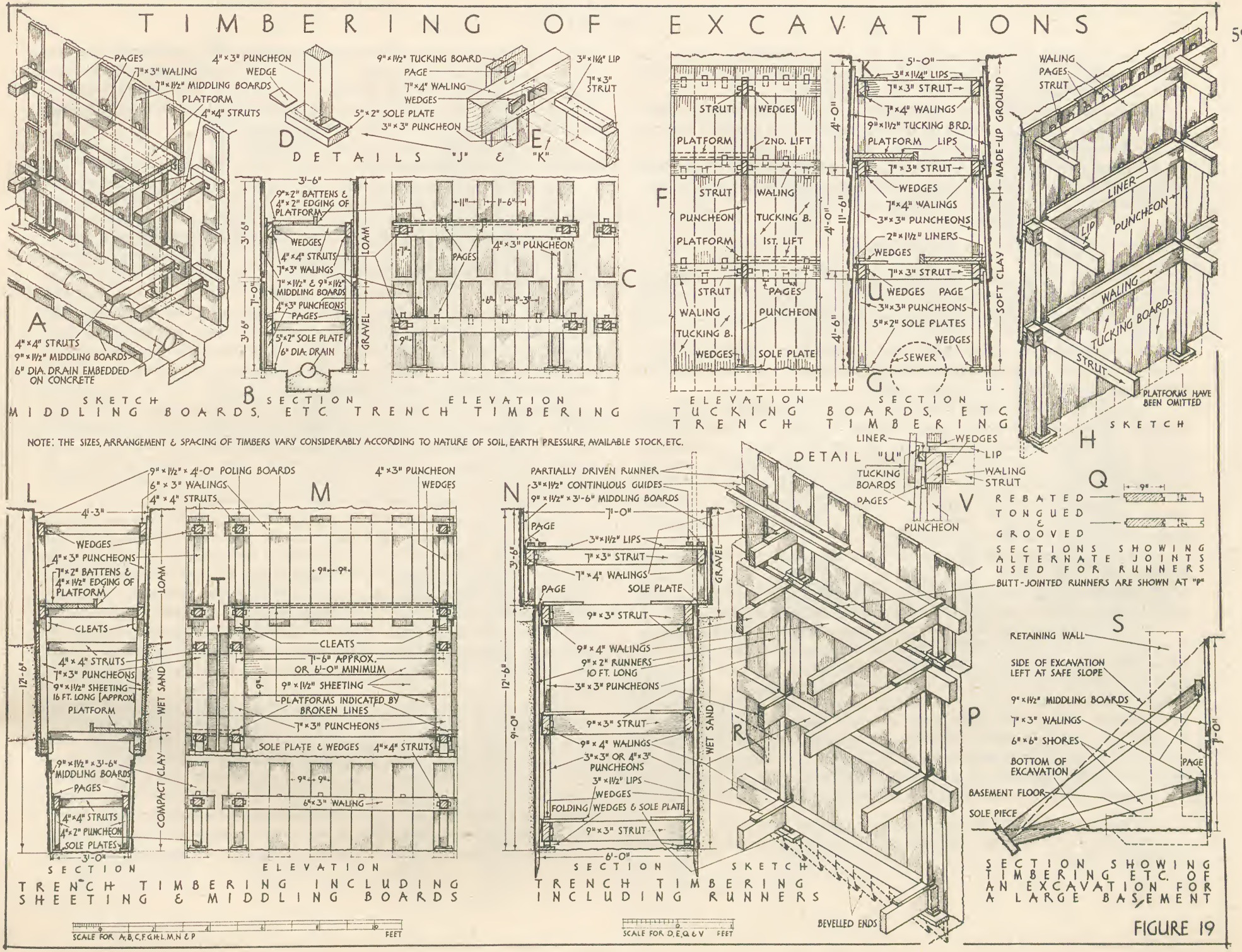
(b) *Runners* (see N and P).—These are generally preferred to sheeting, especially for deep excavations in bad ground. Runners are roughly sawn timbers from 2 to 3-in. thick, 6 to 9-in. wide and up to 20-ft. long. They may be square edged, as shown at P, rebated, or tongued and grooved (see Q). Rebated runners are very effective for close timbering, but the t. and g. type is not now favoured, as the grooves and tongues are readily damaged and small stones are apt to clog the grooves and impede the driving operation. The lower ends or toes are bevelled and shaped as shown to give a cutting edge ; this facilitates insertion and forces each runner against the edge of that previously driven. These runners are driven in by blows from a heavy mallet, and their heads are often bound with hoop iron to protect them from damage. The toes are also sometimes shod with steel or hoop iron, especially if the runners are to be driven through a hard stratum.

In the section at N, the upper 4-ft. of soil is moderately firm and is supported by a setting of middling boards. But below this, wet clay or soil which lacks cohesion necessitates the employment of close timbering. Horizontal *continuous guides*, consisting of two 3-in. by 1½ or 2-in. stuff, are nailed to the top lips with a space between through which the runners are passed. The top frame for the runners is fixed, the walings being packed out from the sides to enable the runners to pass down behind them. The runners are driven down, one at a time, as far as possible without exerting such force as would damage their heads. The excavation is then proceeded with, leaving about 9 to 12-in. of their lower ends buried. Driving is recommenced, followed by the removal of more soil. When the excavation has been lowered to some 4-ft. below the top runner frame, a second frame is fixed and puncheoned ; the lower walings serve as an additional guide and ensure the vertical driving of the runners. The latter are driven in this manner until the necessary depth is reached, frames being fitted at about 4-ft. intervals. In some soils, the runners, because of their weight, can be forced into the ground for several feet before driving is resorted to. The sides of the excavation must always be supported, and hence the importance of not exposing the feet of the runners. A partially driven runner is shown at N and P, the toe of which is about a foot below the bottom of the intermediate cutting indicated by a broken line at R ; the pile must be driven farther before more soil is excavated. Pages are inserted behind the walings as required (see N). These and the strut wedges are slightly eased to facilitate the driving and prevent disturbance of the walings and struts. It is often necessary to provide scaffolding for the men when driving the runners. Such may be dispensed with if the ground will permit the employment of an upper setting of middling boards and correspondingly reduced length of runners. If the runners are required to extend for the full depth of the excavation, the top frame is fixed at the surface, and the continuous guides are strutted at some 2 or 3-ft. above the ground.

*Drainage.*—The admission of water to trenches will add discomfort to the men working in them (and thereby affect adversely the quality of the work) and may cause the timbering to collapse by converting the soil (such as loamy clay or chalk) into a liquid consistency. Steps should therefore be taken to exclude surface water, and remove any which would otherwise accumulate in the trenches. Surface water is dealt with by cutting small channels or *grips* which are given a fall away from the excavations. A trench in a waterlogged soil is usually drained by means of a grip cut at the bottom and along one side of the excavation, and given a fall towards a convenient point where a hole or *sump* is formed to receive the water which is removed by pumping.

LARGE EXCAVATIONS (see S).—This shows the application of timbering to the sides of an excavation such as is required for the construction of the basement of a large building. Mechanized plant is now available for the general or *bulk* excavation of such sites. As much of the ground as possible is excavated, the sides being sloped off at a steep inclination (see thick broken line). The excavation near the sides is then proceeded with, the vertical faces being supported temporarily by middling boards, etc., depending upon the nature of the soil.

# TIMBERING OF EXCAVATIONS




NOTE: THE SIZES, ARRANGEMENT & SPACING OF TIMBERS VARY CONSIDERABLY ACCORDING TO NATURE OF SOIL, EARTH PRESSURE, AVAILABLE STOCK, ETC.

FIGURE 19

These are supported by walings which, in turn, are maintained in position by inclined struts or *shores*. The feet of the latter abut against stout timber sole pieces, or wood platforms, well anchored into the ground.

Sometimes patent interlocking sheet piling of steel is used instead of timber. These are driven in, like runners, trenches are excavated, the retaining walls are constructed and the bulk excavation is then carried out.

The sides of smaller general or site excavations are often supported by runners, walings and long baulk timber horizontal struts propped vertically at intervals.

These methods are described more fully in Vol. IV.

## CENTERING

Centres up to 6-ft. span are described on pp. 83-85, Vol. I. Most syllabuses of Building Construction, Second Stage, include centering suitable for spans not exceeding 10-ft., and typical examples of these are illustrated in Fig. 20 of this volume.

The construction of centres differs widely according to the shape, span, width of soffit and the material of which the arches are to be constructed, in addition to the scantlings of the timber available.

A centre must be of sufficient strength to temporarily support the load to be imposed without distortion, and it must therefore be designed to resist the compression and tension stresses set up during and after the construction of the arch (see p. 62). Being a temporary structure, it must be economical in material and capable of quick construction. Folding wedges must be provided to permit of vertical adjustment, such as the slight raising or lowering of the centre into correct position prior to the construction of the arch, and for its subsequent easing and striking with the minimum vibration.

Centres for Pointed Arches.—An example, suitable for the Venetian arch illustrated at L, Fig. 19, Vol. II, is shown at M and N, Fig. 20. Each rib, to which laggings are fixed, is well nailed to upper and lower ties or *stretchers*. The construction is similar to that shown for the semicircular arch at J, Fig. 43, Vol. I.

Centre for Circular or Bull's-eye Arch (see E, F and G).—This opening is to receive a fixed or pivoted light, the frame of which is fixed in the recess. The lower half of the brickwork is constructed as explained on p. 51, Vol. II. This must be allowed to set before the centre is placed in position. The centre consists of two portions, one for the external purpose-made arch and the other for the rough arch,[1] and it rests upon wedges supported by struts. It will be noted that no laggings are used for the external arch, as they are not required when the width of soffit is only $4\frac{1}{2}$-in. Neither have they been employed for the inner arch on account of the small span. If necessary, a short cross-brace may be nailed centrally to the underside of the upper ties. The outer portion consists of a pair of ribs nailed to upper and lower ties; sometimes only one rib is used for such a small span. Because of the greater width of soffit the inner centre requires two ribs, placed at approximately 7-in. centres, nailed to two pairs of ties. In lieu of struts the wedges of each portion may be supported on a ring of bricks laid dry on the lower half of the arches.

The elevation of the inner portion of the centre has been omitted at E; but for the sizes of the members this is similar to that of the outer portion shown.

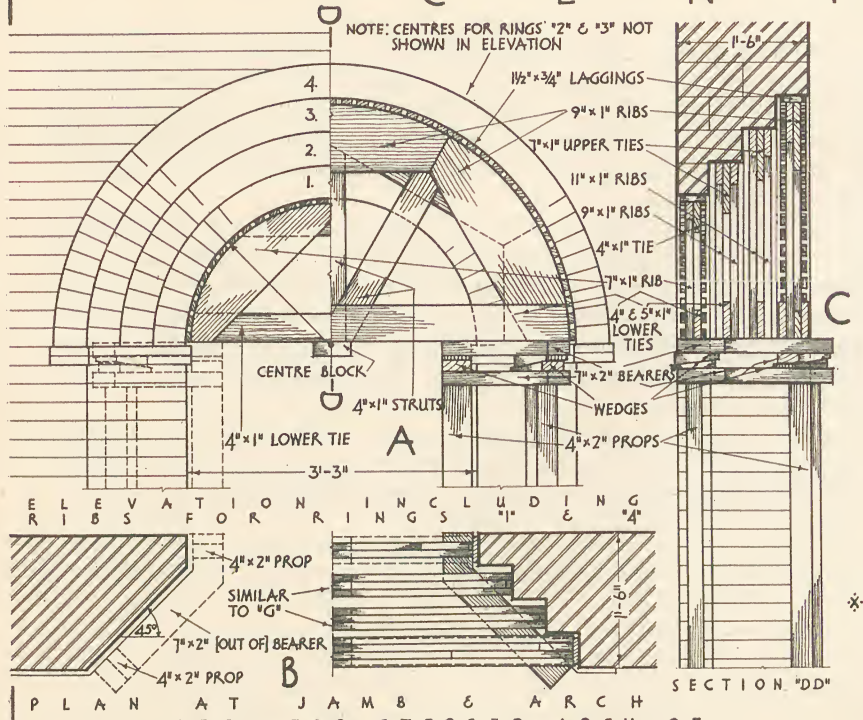
Centre for Semicircular Arch with Orders.—The centre illustrated at A, B and C, Fig. 20, is suitable for the head of the entrance shown at A, Fig. 19, Vol. II. In effect, this is a compound structure consisting of a centre for each of the four rings. The centre for the inner ring, which is first erected, is similar to that shown at J, Fig. 43, Vol. I. Laggings, as shown, are sometimes used, but as the soffit is only $4\frac{1}{2}$-in. wide it is usual to dispense with them and employ a centre similar to those shown for rings 2 and 3; when the span is small the latter type may be further simplified by the omission of one of the ribs. As indicated on the plan B, the centres for rings 2 and 3 may be of the type shown for the outer arch at G, described above. The centre for the outer ring 4 is of the type shown at M, Fig. 43, Vol. I, and needs no further description; here again the laggings may be omitted.

Because of the projecting tiled impost (see A, Fig. 19, Vol. II), the lower ties are slightly above the centre to which the voussoirs of each ring radiate. It is therefore desirable to use a short centre block for each wood ring centre, with a space between each (see broken lines on plan) to permit of the use of radius rods or lines, as described on p. 24, Vol. I. In order to simplify the drawing, these blocks have been omitted from section D-D.

Some bricklayers prefer to bring into use each ring centre only as required. Thus, that needed for ring "2" would not be placed into position until ring "1" was built, and the outer centre would not be placed on its supports until after the construction of ring "3." This provides for greater accessibility and there is less likelihood of the brick voussoirs being stained from extruded mortar during construction. This also enables the individual adjustment of the centres preparatory to the construction of each ring, as the upper bearers would not be continuous, as shown, but each centre would have a short bearer nailed to each end of the lower ties, with small wedges between it and the lower continuous bearer.

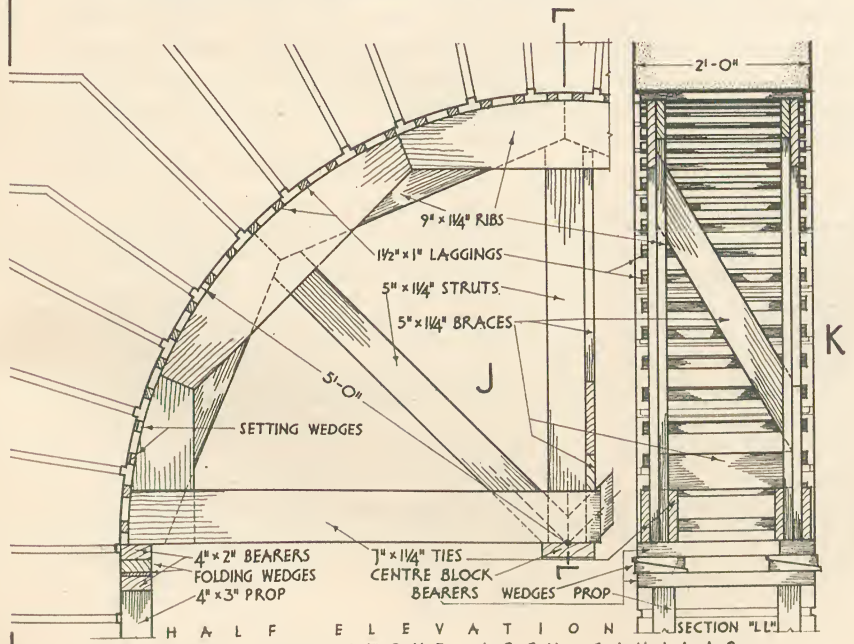
Centre for Semicircular Stone Arch (see J and K).—This arch is similar to that shown at A, Fig. 37, Vol. II, the span being increased to 10-ft. in order to illustrate a centre having the maximum span stated in the syllabus. The construction closely resembles that of the centre shown at M, N and O, Fig. 43, Vol. I. Each built-up rib of 9-in. by $1\frac{1}{4}$-in. stuff is connected at its feet by two 7-in. by $1\frac{1}{4}$-in. ties. Two inclined struts or braces and a vertical central strut or post are provided in addition to an inclined cross-brace and a horizontal cross-brace. The members must be well nailed at the joints to ensure rigidity. Two stout laggings per voussoir are shown. Setting wedges may be used (two are shown

[1] The lower half of this rough arch need only consist of one ring (see sketch G) if the internal face is to be plastered; otherwise it may be formed of two rings as suggested by the broken lines at E.

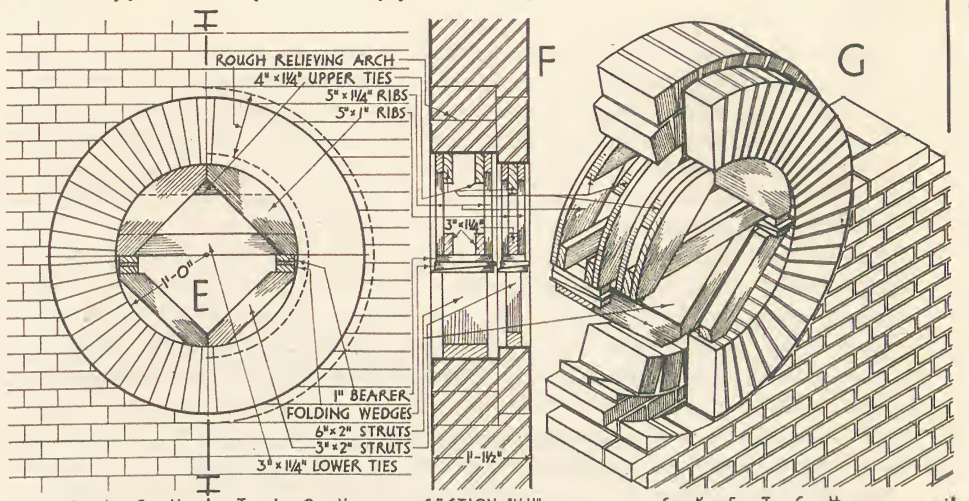



CENTRE FOR STEPPED ARCH OF DOORWAY SHOWN AT "A", FIG. 19*

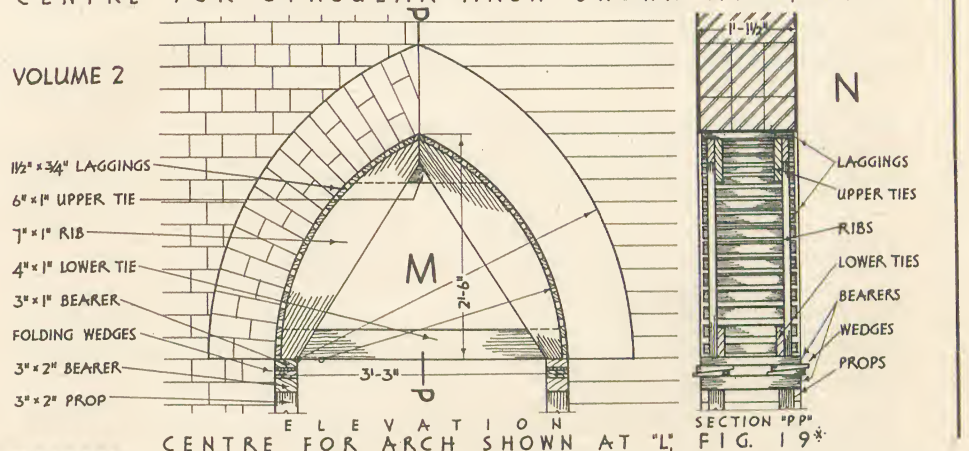
* INDICATES VOLUME 2



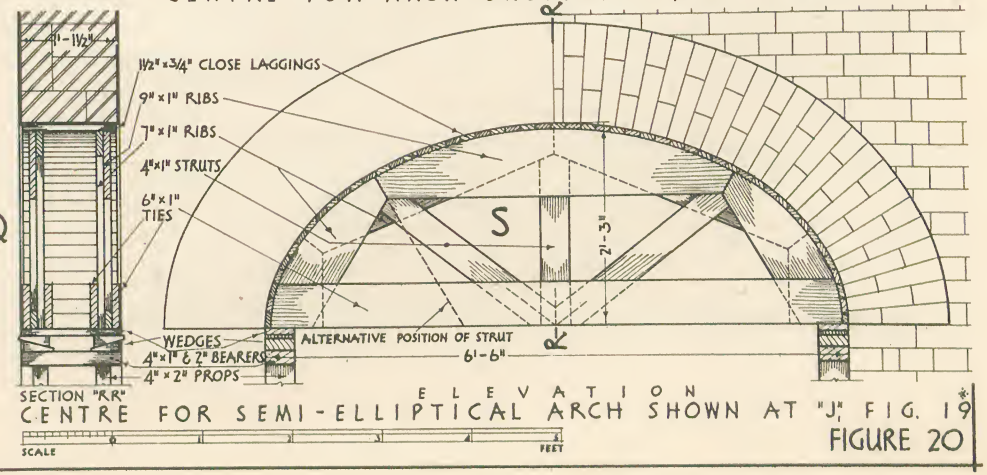

CENTRE FOR STONE ARCH SIMILAR TO THAT SHOWN AT "A", FIGURE 37*




CENTRE FOR CIRCULAR ARCH SHOWN AT "H", FIG. 19*




CENTRE FOR ARCH SHOWN AT "L", FIG. 19*




CENTRE FOR SEMI-ELLIPTICAL ARCH SHOWN AT "J", FIG. 19*

FIGURE 20

supporting the second voussoir at J) instead of laggings, four (two supported on each rib) small hardwood wedges being required per voussoir. As each stone voussoir is accurately dressed to the required shape, the centre merely serves as a support and need not necessarily be cut to the true shape of the soffit if setting wedges are used to bring individual voussoirs to the correct bedding position.

It has been stated on p. 60 that a well designed centre must be capable of resisting the stresses produced during the construction of the arch. These stresses vary as the work proceeds. Thus, in the early stages of construction, the weight of the haunches is partially resisted by the ribs and the inclined compression members or struts ; the load tends to distort the ribs by thrusting their lower ends inwards and their upper ends upwards, and the downward forces acting along the struts tend to depress the lower end of the central vertical post or strut. The latter, being well nailed to the rib at its top end, resists these forces and at the same time restrains the upward thrust through the ribs ; the post is in tension. During the construction of the upper portion of the arch the additional weight has a tendency to depress the crown and force the lower ends of the ribs outwards. This is resisted by the ties (which are now in tension) and the struts. In effect, the centre acts in a similar manner to a king post roof truss, the ribs (like the principal rafters of the truss) are in compression, the inclined struts are in compression, the lower ties resemble the tie beam of the truss as they are in tension, and the central post (functioning like the king post of the truss) is in tension.

Centre for Semi-elliptical Arch (see Q and S).—The arch is illustrated at J, Fig. 19, Vol. II. The construction follows closely that described on p. 60. The joints between the pieces forming the built-up ribs are normal to the curve. The struts may also be fixed as normals to the intrados (see thick broken line) as an alternative to those shown. Close lagging is shown as a contrast to the open lagging indicated in the other examples. The geometrical construction of the intrados and extrados is described on p. 52, Vol. II.

For spans exceeding 14-ft. the larger members of the centres are usually framed together like a roof truss, and the joints are made rigid by the employment of $\frac{1}{2}$-in. diameter bolts in lieu of nails. These are detailed in Vol. IV.

CHAPTER TWO

# JOINERY

*Syllabus.*—Doors, including fanlights, semicircular headed, glazed and flush. Windows, including semicircular headed boxed frame with sliding sashes, boxed frame with three lights, and metal. Stairs; terms; types; essential requirements; step proportions; construction and detailing of straight flight, dog-leg and open well[1] stairs; open and solid balustrades; winders; special steps. Manufacture, characteristics and uses of plywood, laminboards, blockboards, battenboards and composite boards.

## DOORS

PANELLED and other types of doors are described on pp. 86-107, Vol. I, and students should re-examine the details of the joints between the members of frames and doors before studying the types described below, *i.e.*, (*a*) doors with fanlights, (*b*) semicircular headed doors, (*c*) glazed doors and (*d*) flush doors.

(*a*) DOORS WITH FANLIGHTS OR TRANSOME LIGHTS (see Figs. 21 and 22).—The former shows at A, B and C a two-panelled door with a glazed upper portion, called a *fanlight* or *transome light*. The essential object of a fanlight is to provide lighting to an outer lobby, hall, etc., and occasionally it is required to serve as a means of ventilation. The horizontal member separating the door and fanlight is called a *transome*, each end of which is double tenoned to the frame. This fanlight is fixed, the seven pieces of glass being secured between small hardwood outer beads (tongued and grooved to the head, transome and posts of the frame), small inner beads (screwed to the frame) and two narrow curved glazing bars to which two curved glazing beads are subsequently screwed (see details at K, L and M). The glass is bedded in putty before the inner beads are fixed in order to exclude water.

> The curved glazing bars and beads are bent in the following manner: The pieces to be bent are first placed in a steam chest or oven where the wood is softened and rendered pliable by the action of steam. This softening process takes approximately three-quarters of an hour per inch thickness of wood. Immediately each piece is removed from the chest, it is curved over a stout wood templet, shaped as required, and a second shaped templet or *caul* is placed over it. All three are tightly clamped together and left until the piece has dried out. As the pieces are apt to spring back slightly after being bent, it is advisable to allow for this and use lengths of timber a little thicker than the finished thickness; the pieces, after being bent, are then worked to the required section.[2]

[1] Consideration of the open well type of stairs is often deferred until the third year of the course.

[2] The following publications of the Forest Products Research Laboratory give much valuable information upon wood bending: "The Practice of Wood Bending," "Methods of Bending Wood by Hand" and "Machinery and Equipment used for Bending Wood."

The transome is weathered, grooved, throated and rebated (see M). The door has two equal $\frac{3}{4}$-in. panels, bolection moulded on the external side and chamfered stuck moulded on the other (see M, N and P). There are, of course, many alternative finishes to panels. Thus, stuck mouldings on both sides are shown at M, Fig. 22, and at O in the same figure a planted mould is shown on one side and a stuck mould on the other; further finishes may be selected from those shown in Figs. 48, 50, 52, etc., Vol. I.

It will be observed that a wood architrave is not required when the frame projects slightly beyond the face of the plaster (see K). As shown, the frame must be grooved to receive the plaster, otherwise shrinkage gaps will occur. Two further examples are shown at K and P, Fig. 22.

In order to prevent the access of water at the floor level, a hardwood threshold is securely screwed to the floor. Any water blown in is caught by the groove and escapes through two bore-holes, indicated by broken lines. The weather board throws water, streaming down the door, clear of the threshold (see p. 98, Vol. I). Alternative details are shown at M and R, Fig. 22, and J, Fig. 24. Small triangular blocks are sometimes placed at intervals between weather boards which are thin and have a relatively big projection (see M, Fig. 22, and J, Fig. 24). The hardwood threshold shown at R, Fig. 22, somewhat resembles a window sill detail; it is most effective but costly.

The stonework of this entrance is detailed at A, Fig. 39, Vol. II.

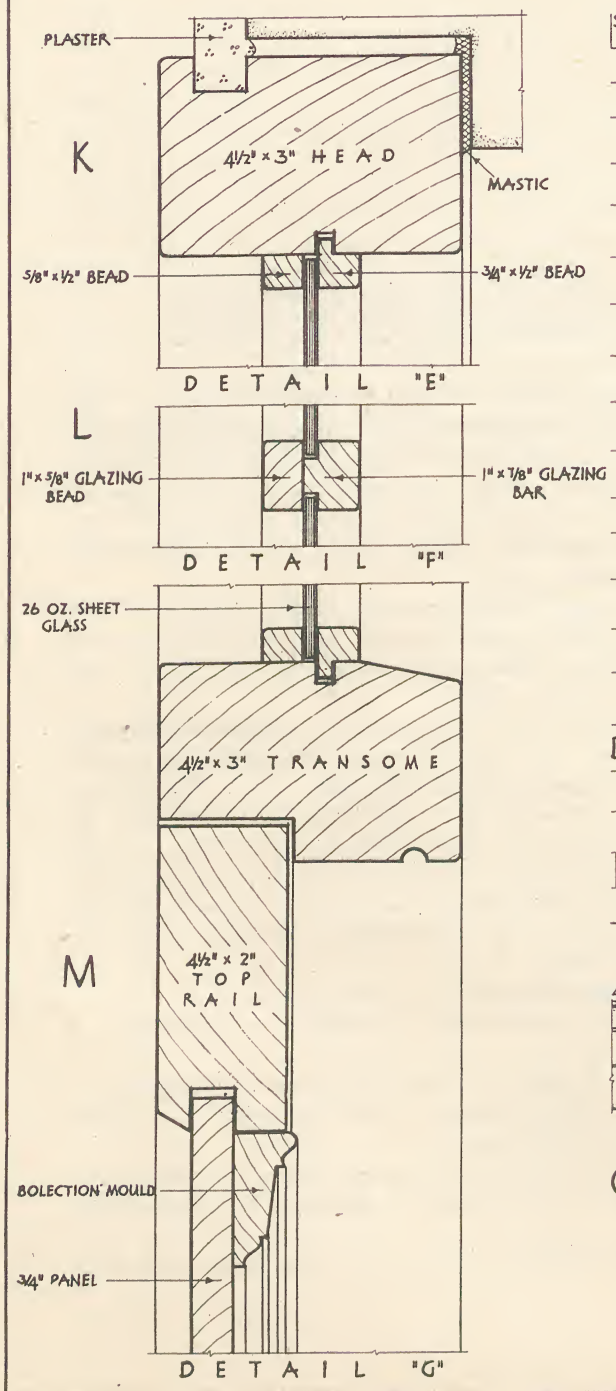
Small scale sections showing various types of fanlights are shown at A, B and C, Fig. 22.

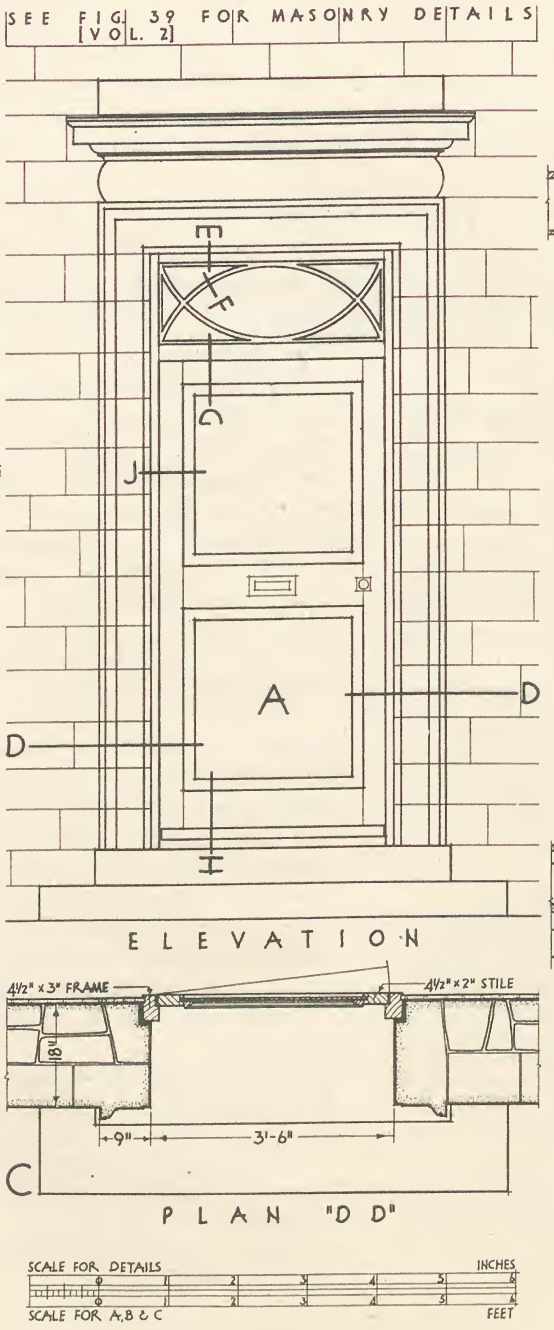
That at A, like the fanlight in Fig. 21, is fixed, the glass being received in a sash (see details at K and L). The front edge of the transome has a narrow raised panel flush with the posts of the frame.

It is seldom that a fanlight is required to open, but if it is, the sash may be either bottom-hung (as shown at B), top-hung (as shown at C) or pivoted (as illustrated in Fig. 62, Vol. I).

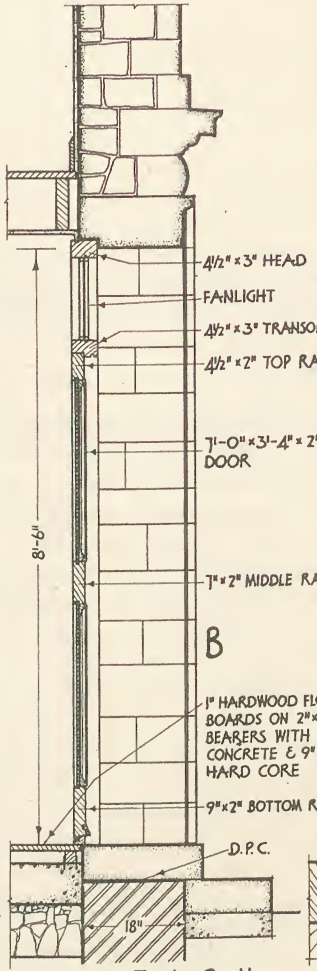
Details of the former type are shown at N and O. The bottom rail of the

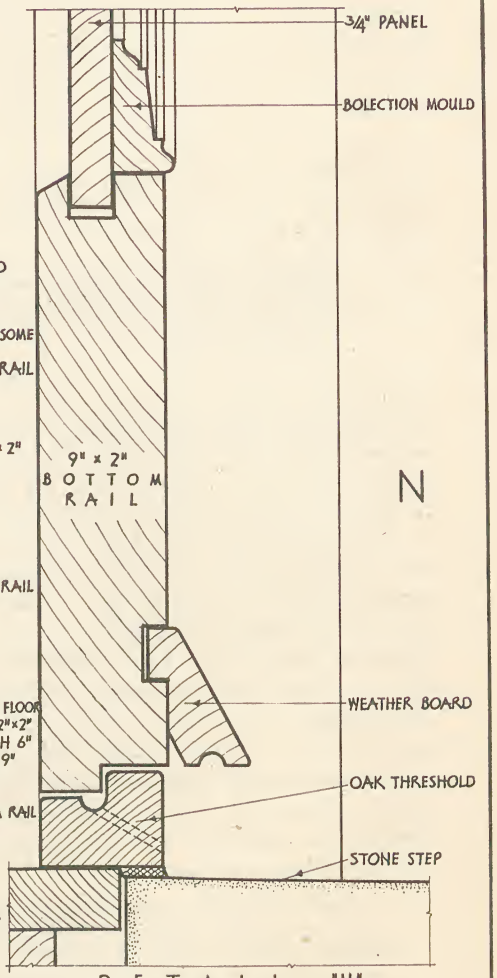
# DOOR WITH FANLIGHT




SEE FIG. 22 FOR ALTERNATIVE DETAILS



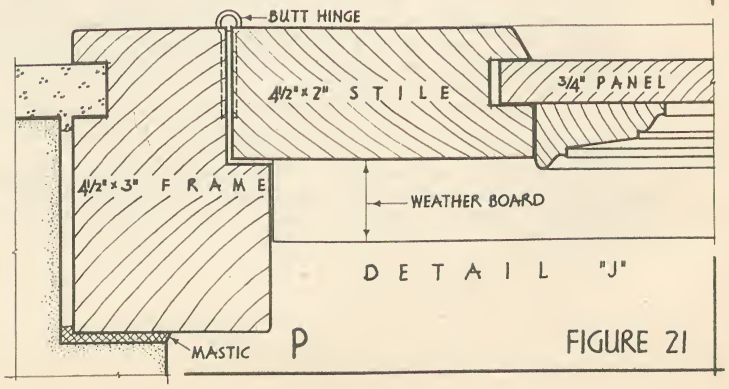




FIGURE 21

# DOOR DETAILS

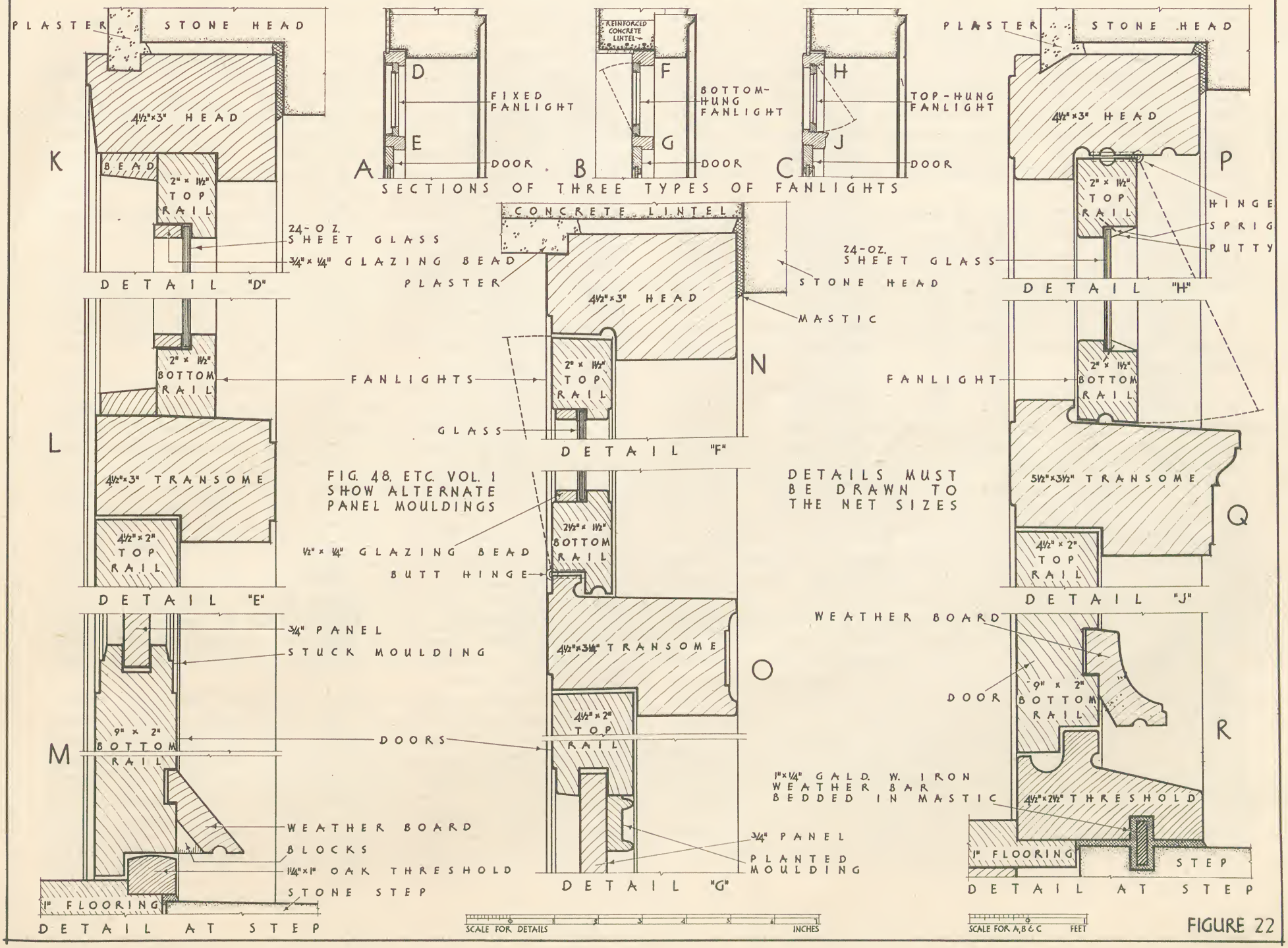



FIGURE 22

sash is fixed to the transome by a pair of hinges. The head of the frame and the top rail of the sash must be slightly splayed, as shown, to permit of the necessary opening clearance. One of several types of gear available for opening and closing the fanlight consists of a small ratchet wheel and bar arrangement, the small wheel fitting and the bar being fixed at one side (preferably the " hanging side " of the door) at the top of the sash and to the frame respectively, and operated by a cord. The details show the usual rebates and capillary grooves (described on p. 111, etc., Vol. I) necessary to exclude water and draughts between the sash and frame. The front edge of the transome is sunk-panelled as an alternative to that at L.

The top-hung transome light at C is detailed at P and Q. The sash is fixed to the head of the frame by a pair of hinges and opens outwards. A casement peg stay (see Fig. 59, Vol. I) will serve to maintain the sash in an open position ; alternatively, a patent opener similar to that described above may be preferred. The transome is moulded, as shown, as a further alternative to those at L and O. All three transomes may be throated, as shown at M, Fig. 21.

The glass may be secured by either putty, as shown at P and Q, or beads (bedded in putty and secured with small brass screws with cups), as shown at K, L, N and O.

(*b*) SEMICIRCULAR HEADED DOOR (see Fig. 23).—The construction of the head of the frame is detailed at D, E and F. These show it built-up of two ribs or " thicknesses," glued and either screwed together or secured by $\frac{1}{2}$ or $\frac{5}{8}$-in. hardwood pins or dowels ; the outer rib consists of three pieces and the inner of two pieces. The joints at the springing between the posts and the head are formed of *hammer-headed key tenons*. These tenons are shaped on the posts and the head is morticed to receive them and the glued wedges (see F). When the two wedges are tightly driven in at each joint the shoulders are brought close together and exceptionally strong joints result. The maintenance of a tight fit is further assured if two small glued *shoulder tongues* (see footnote to p. 72), as shown, are employed, but these are often dispensed with. These springing joints may be formed of loose hammer-headed keys similar to that used at the crown of the door (see J, K and L) or by handrail screw bolts (see Q, Fig. 26) and hardwood dowels, but these are less effective than the tenon shown at F.

The construction of the head of the door is shown at J, K and L. The head consists of two pieces which are jointed at the crown. The joints between the stiles and the head are similar to those of the frame, the hammer-headed tenons being formed on the stiles ; the upper tapered portion of the tenon (and mortice) is commonly cut square (and not radial as shown) to facilitate the entry of the tenon. It will be observed, however, that these radial joints are slightly ($1\frac{1}{4}$-in.) above the springing. This is necessary because of the presence of the top rail which is, of course, tenoned into the stiles. Very weak joints would result if they coincided with the springing. Shoulder tongues are not necessary because of the reduced thickness of the framing. A hammer-headed key joint is shown at the crown. This is tightened up by means of the four small glued wedges. A handrail screw bolt and dowels or pins may be used in lieu of the key (see Q, Fig. 26).

One or more of the central panels of the door may be glazed, as shown at A, B and C, antique glass (tinted glass) being specified. The small glazing bars are stub-tenoned (see K). Enlarged details of the door are shown at G and H. These indicate an entire absence of mouldings, the arrises of the rails, muntins, stiles, frame, etc., being pencil-rounded, *i.e.*, rounded off by sand-papering. The small simple architrave conforms. A weather board is not considered to improve the appearance of a door, and in this example it has been omitted, as it is assumed that the door opens into an outer lobby. A weather board and threshold, as illustrated in Figs. 21 and 22, are, however, necessary to exclude water if the entrance is in an exposed position and if the door opens directly into a living-room or hall.

This entrance is also illustrated at A, B and C, Fig. 19, Vol. II. Because of the reduced thickness of the splayed brick jambs at the door frame, it is especially necessary for the brickwork to be constructed of sound materials and workmanship if dampness is to be avoided. Under certain conditions, such as excessive exposure, it may be desirable to increase the thickness by $4\frac{1}{2}$-in. for the full width of the lobby.

(*c*) GLAZED OR SASH DOORS (see Fig. 24).—These are wholly or partially glazed and are adopted to light lobbies, halls, corridors, landings, etc., occasionally to supplement the lighting provided by windows, or to make the interior of one room visible from another. Several designs, most of which are of doors now mass-produced on a large scale, are illustrated at A to H inclusive.

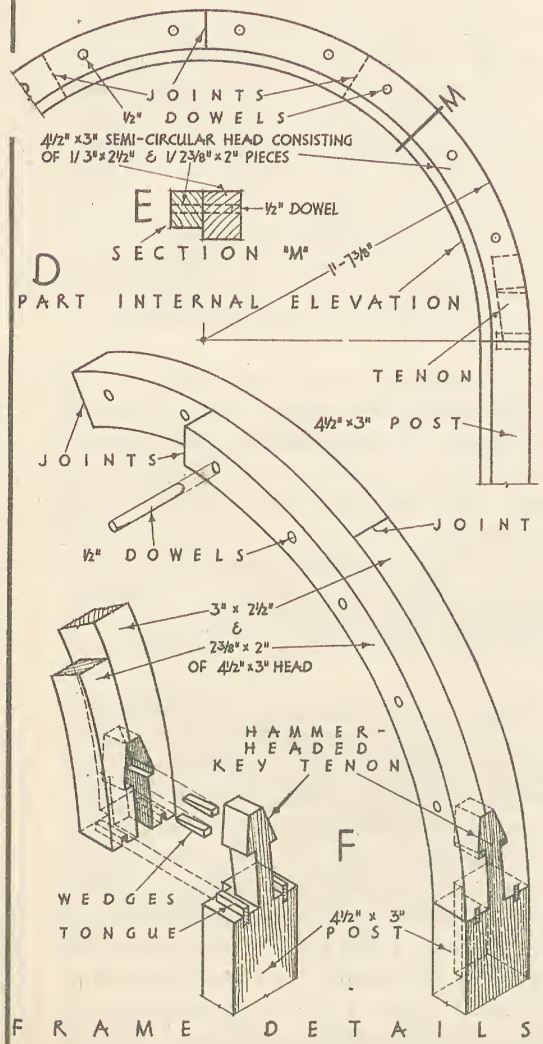
The joints between the stiles and rails of the door framing are either morticed and tenoned or dowelled (see p. 98, Vol. I). The joints between the glazing bars are usually tenoned and scribed (see p. 108, Vol. I).

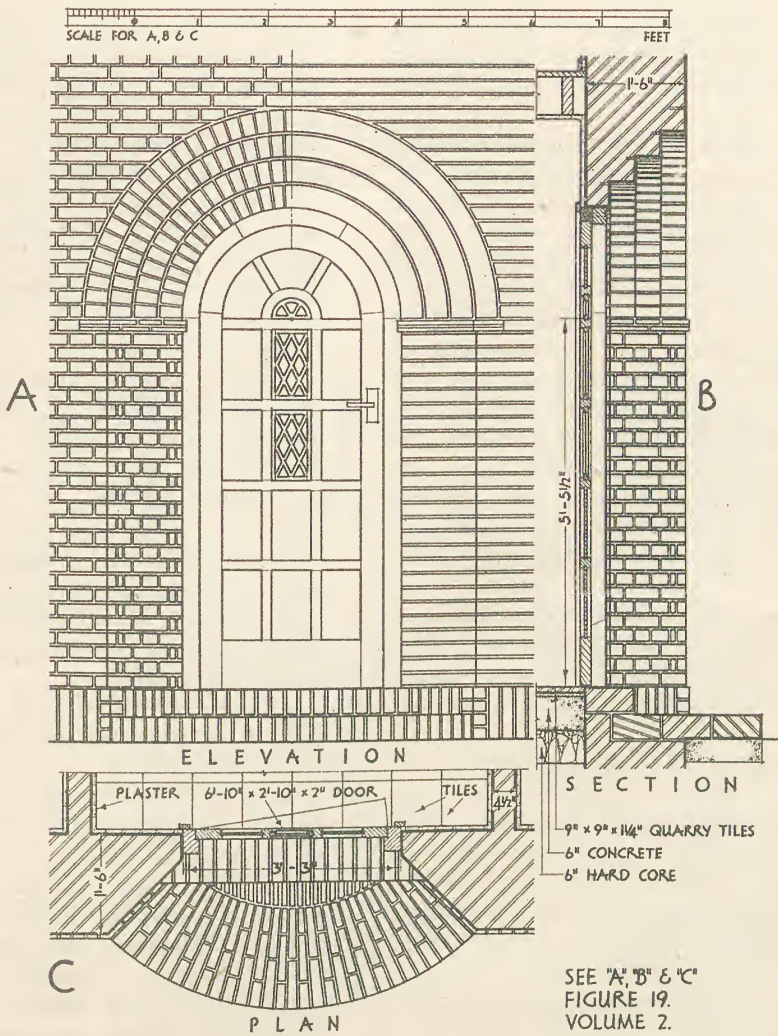
*The details on this and other sheets show architraves, panel moulds, etc., of various shapes and sizes. The reason for this is to provide for reference a wide range of sections, and it must not be assumed, therefore, that any particular moulding is the most appropriate for the detail concerned. Further, whilst for the above reason, two different architraves are shown in each of the details* K, T *and* P, *it is customary in practice to adopt a common section throughout a building or for similar rooms on the same floor. Glass shown fixed with glazing beads may be secured with sprigs and putty, and vice versa.*

The five horizontal panels of the door A are of glass. The detail at J shows the glass bedded in putty and beaded. The weather board is alternative to those shown in Figs. 21 and 22, and the wrought iron water bar, caulked with lead and covered with cement (see p. 98, Vol. I) is alternative to a hardwood threshold. It is again noted that persons are more apt to trip over a bar, which has only a small projection, than over the more conspicuous thick wood threshold.

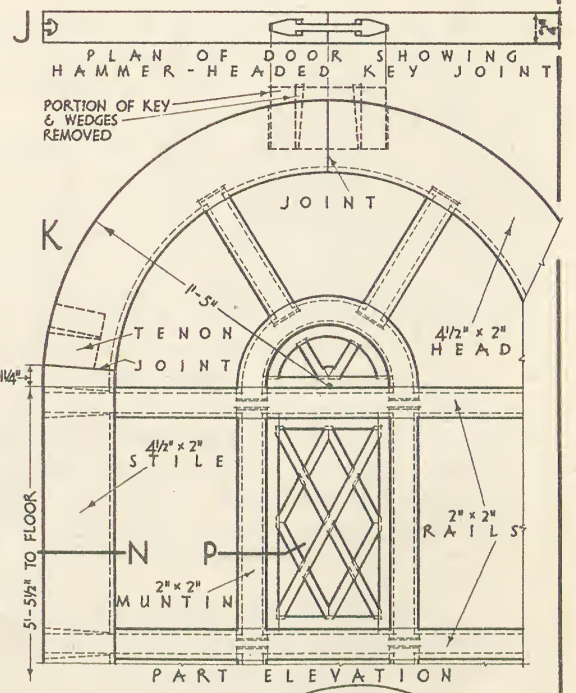
The fifteen glass-panelled door at B is detailed at K. The small half-round architrave is shown with a plinth block to provide a suitable finish for the skirting. Alternatively, if a thicker skirting is used, as shown by the broken line, the blocks

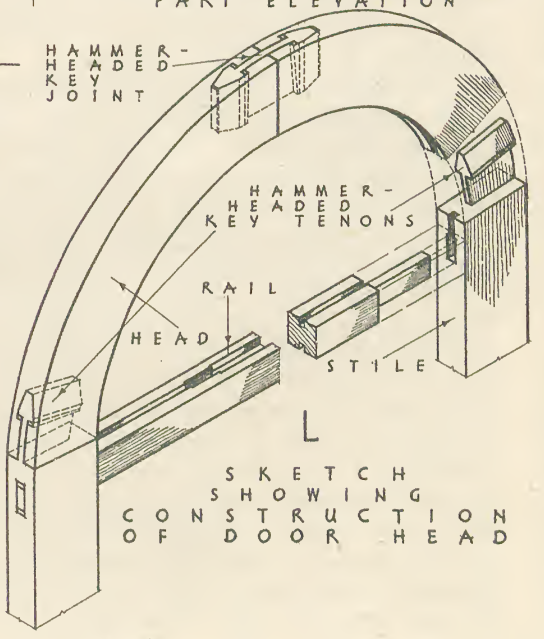
# SEMI-CIRCULAR HEADED DOOR

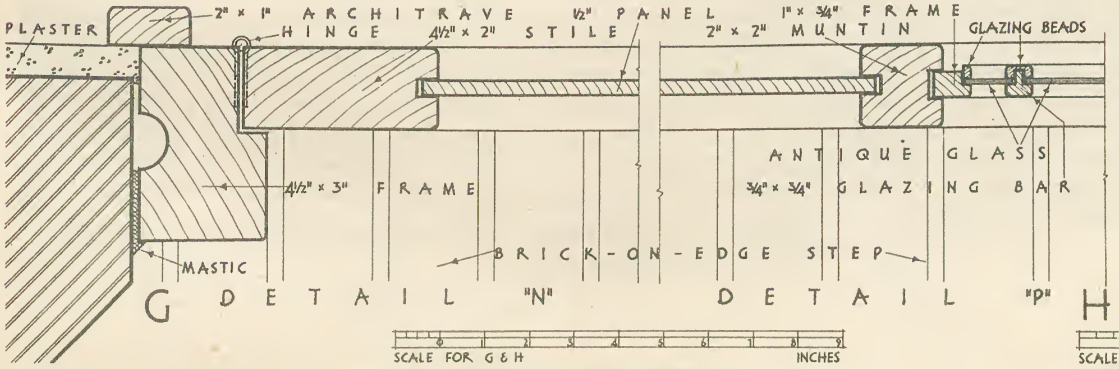



SEE "A", "B" & "C" FIGURE 19. VOLUME 2.




NOTE: NOMINAL SIZES ARE SPECIFIED & THE DETAILS HAVE BEEN DRAWN TO FINISHED SIZES.

FIGURE 23

may be dispensed with and the skirting finished with a curved end against the casing ; the feet of the architrave would then be mitred to the upper splayed edge of the skirting. The ovolo moulded glazing bead conforms with the stuck moulding on the opposite side.

Each of the eighteen glazed panels of the door at C is proportioned in accordance with the construction shown at T, Fig. 60, Vol. I, *i.e.*, the height equals the hypotenuse of a square which has a length of side equal to the width of the pane. Three alternative details of the wide bottom rail are shown at M, N and O. That at N shows a compound rail, the lower portion being sunk-chamfered both sides and tenoned into the upper. Alternatively, as shown at M, the lower rail may be tenoned into the upper and finished flush on one side with a double bead, and having a similar beaded mould inserted in the other. The alternative finish at O shows a narrow $\frac{1}{2}$-in. thick panel. As an internal door should be kept $\frac{1}{2}$-in. from the floor to allow it to swing clear of a carpet with underfelt, draughts may be minimized if, as shown at N, a splayed hardwood slip is well screwed to the floor ; this is an alternative to that shown with rounded edges at J, Fig. 52, Vol. I. Of course, such provision is not necessary if the doors are hung with skew butt hinges (see Z, Fig. 45, Vol. I). The details at M and N show the glass fixed with glazing beads ; as an alternative, the glass at O is shown sprigged and puttied.

The single panel of the door at D is of glass. The detail at L shows that architraves have been dispensed with and the projecting casing finished with rounded edges. The casing is grooved to receive the plaster and a $\frac{1}{2}$ or $\frac{3}{4}$-in. stop is nailed to it. Because of the large size of the sheet, $\frac{3}{16}$-in. polished plate glass has been specified.

The upper panel only of the door at E is glazed ; a detail is provided at S.

A portion of the door at F is glazed. The detail at T shows a thick (1-in. nominal) panel finished with large bolection mouldings on both sides. The glazed sash, divided into four small panes, is grooved on its outer edges and engaged in the panel. The architrave at the bottom of the detail is shown finished on the splay of the skirting. Alternatively, the latter may have the same projection and a similar moulding as the architrave, to provide a mitred joint.

The old-fashioned *diminished stile door*, still occasionally used, is illustrated at G. It has either one or two wood panels at the bottom, and the upper portion is glazed. In order to provide the maximum area of glass, the width of the upper portions of the stiles which receive it is decreased. Hence the terms *diminishing stiles* and *gun-stock stiles* which are applied to these vertical members. The joint between the middle rail and stile is shown at R, the latter being diminished from $4\frac{1}{2}$ to 3-in. nominal. The development in this sketch presents a somewhat peculiar appearance due to the opposite shoulders not being parallel. If required, a stuck moulding of width equal to the depth of the glazing rebate could be worked on the rails and stiles, and parallel shoulders would result. A vertical section through the middle rail is shown at Q, and a detail at one of the jambs above this rail is illustrated at P.

An external entrance is shown at H. The brickwork at the jambs has three $1\frac{1}{2}$-in. deep recesses (see inset plan) which are continued at the head formed of purpose-made voussoirs. The door has an octagonal shaped glazed panel divided by glazing bars. A detail of this door and frame is shown at U. It is somewhat similar to that at T, except that it is bolection moulded on one side only and the thick panel is raised and fielded. Being an external door, the glass is tinted or otherwise obscured. In the detail it is assumed that the frame is set back slightly from the inner recess. If, as shown in the part plan at H, the door is set farther back, the detail at the frame will be similar to either of those shown at P, Fig. 21, K and P, Fig. 22, or G, Fig. 23.

The door illustrated in Fig. 23 is partially glazed, as is also the flush door at C, Fig. 25.

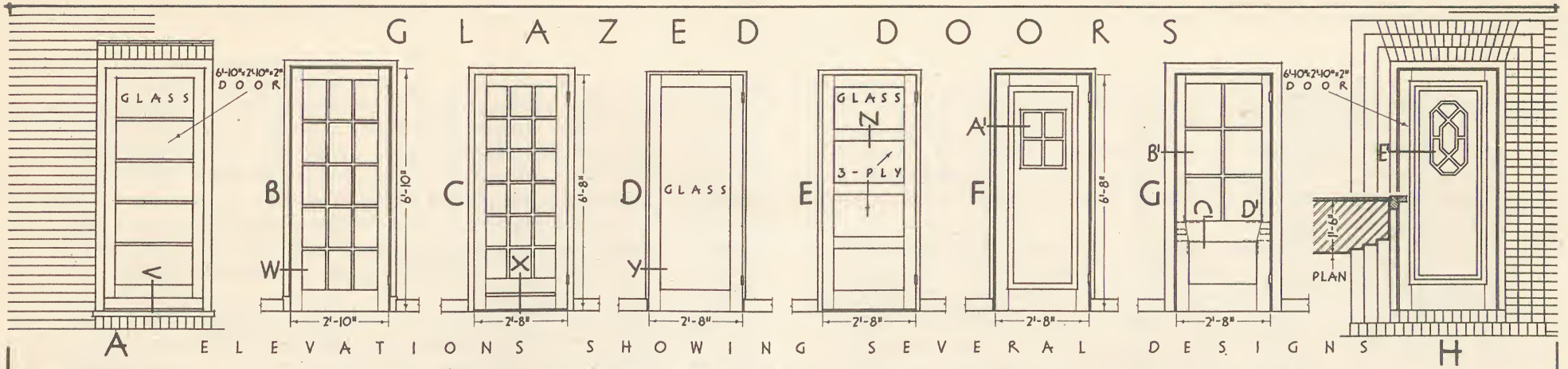
(*d*) FLUSH DOORS (see Fig. 25).—These doors, faced with plywood,[1] are described on pp. 94 and 95, Vol. I. A selected few of the various types are illustrated at A to E inclusive. Most of these are mass-produced. The standard sizes are 6-ft., 6-ft. 4-in., 6-ft. 6-in., 6-ft. 8-in., 6-ft. 10-in. and 7-ft. high, 2-ft., 2-ft. 4-in., 2-ft. 6-in., 2-ft. 8-in., 2-ft. 10-in. and 3-ft. wide and $1\frac{1}{2}$ to 2-in. thick.

A flush door may consist of either a skeleton or hollow frame covered both sides with plywood (see A, B, C and E), or it may have a solid core throughout with plywood facings (see D). Most mass-produced flush doors are of the skeleton framed type, chiefly because of the great economy in the amount of timber which results.

The hollow framed flush door shown at A is detailed at F. The frame consists of 4-in. by $1\frac{1}{2}$-in. (nominal) stiles, top and bottom rails, and 2-in. by $1\frac{1}{2}$-in. intermediate rails at 6 to 9-in. centres ; alternatively, 3-in. wide intermediate rails at approximately 1-ft. centres may be employed. These rails are mortised, tenoned and glued to the stiles, the tenons preferably extending the full width of the stiles as shown at Q. The intermediate rails are glued, tenoned and cramped into the continuous grooves formed in the stiles (see F and R). Ventilation holes, as shown, should be provided to ensure a thorough circulation of air within the framing ; care should be taken to see that those in the top rail are not subsequently " stopped " with putty by the painter. For good class doors the plywood facings should be $\frac{1}{4}$-in. thick ; $\frac{3}{16}$-in. 3-ply is only employed on cheap doors. Edging slips, especially on the striking stiles, are necessary. Several forms of these are shown at F, H and J. If, as shown at G, no such provision is made and the plywood is continued to the outer edges of the stiles, the plywood is readily damaged by splintering, especially if the door swells on account of the absorption of moisture, and a tight fit between it and the casing results. Edging slips are fixed on all edges of good class doors. A lock block should be provided, as shown at A, to allow for the insertion of a mortise lock. The position of this should be indicated on the outside, otherwise a block is provided at each side,

[1] A description of the manufacture, characteristics and uses of plywood, laminboard and blockboard is given on pp. 97-103.

# GLAZED DOORS




A ELEVATIONS SHOWING SEVERAL DESIGNS

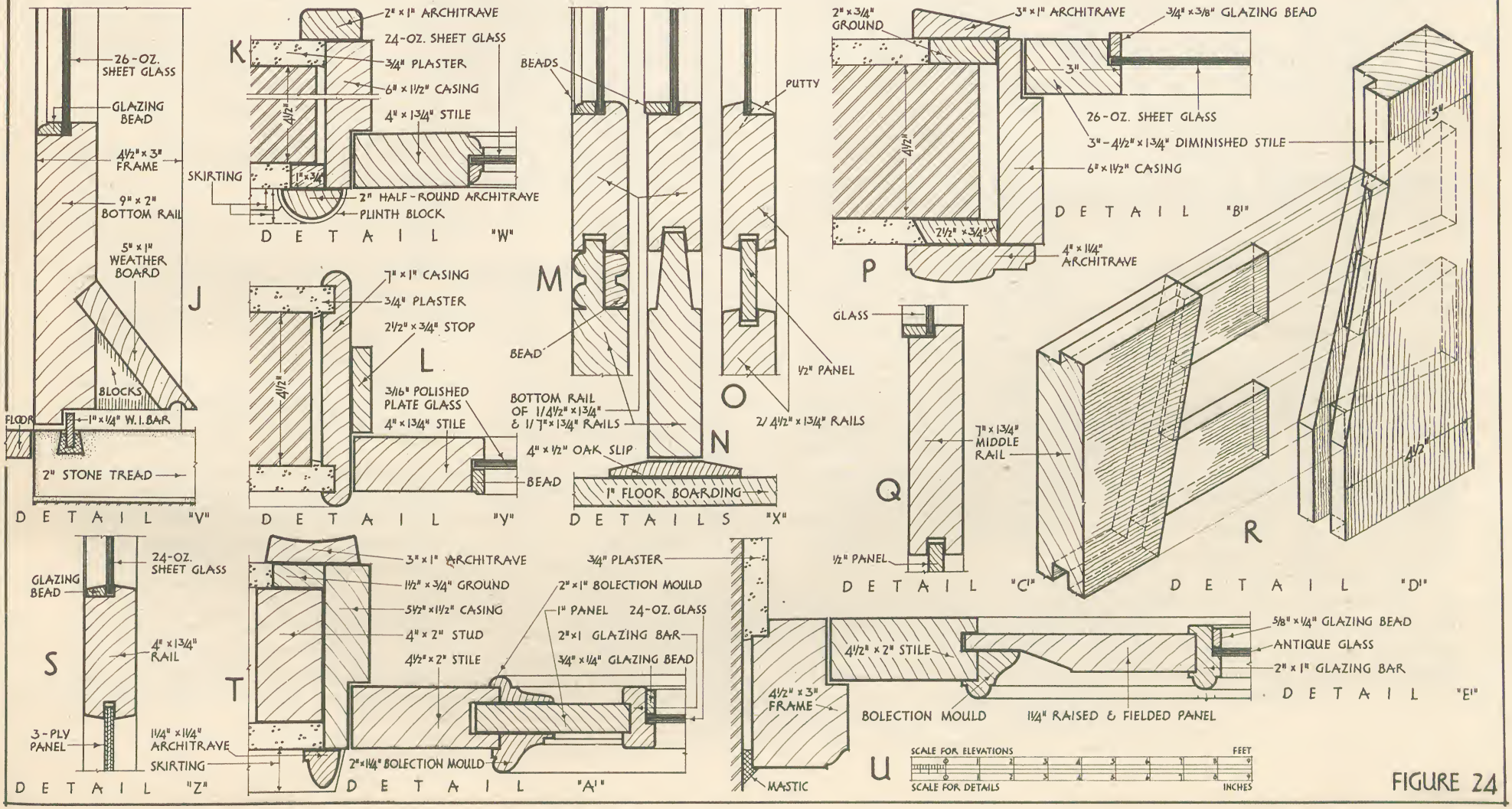



FIGURE 24

as shown at E; in mass-produced doors these lock pieces are increased in length in order that the position of the lock may not be unduly restricted. The wide architrave (which should be in at least two pieces, if it exceeds 6-in., to prevent splitting if shrinkage occurs) is shown at A with rounded corners. To prevent opening at the mitres the joints should be either cross-tongued (see footnote to p. 72), or the horizontal member should be tenoned into the verticals and screwed from the back.

The framed flush door shown at B and G is that referred to in the specification "War Emergency British Standard 459: 1942."[1] The object of the specification is to ensure an economy in the use of timber. As shown, the skeleton framing consists of very light members, *i.e.*, 1½-in. by 1-in. stiles, top and bottom rails, ⅜-in. vertical ribs at not more than 5-in. apart housed ⅛-in. into the outer rails, and ¾-in. (minimum) wide horizontal ribs, not exceeding 12-in. apart, glued to the vertical ribs and stiles. The top and bottom rails may be either dovetailed into the stiles, or the latter may be double tenoned into the rails, or the corners may be *combed jointed*, *i.e.*, corrugated metal saw-edge fasteners (see Fig. 66, Vol. I) are driven in. The framing is reinforced with 1-in. wide blocks at the hinges and lock block. Each side is covered with plywood of a minimum thickness of $\frac{3}{16}$-in. This covering is shown at G finished flush with the edge; as explained on p. 68, this may result in the fraying of the edges of the plywood. As a protection against damage, an external door has a 9-in. by $\frac{3}{16}$-in. (3-ply, resin-bonded) *kicking plate* fixed at the bottom at each side. This plate or ledge has its top edge bevelled.

The semicircular headed door at C, detailed at K, has a small glazed panel. The head of the door framing may be in two pieces only, with the central joint combed or cross tongued; or alternatively, it may be built-up in two thicknesses like the frame at D, Fig. 23, described on p. 66. The joints between the head and the stiles may be either tenoned, as shown, or they may be combed jointed; hammer-headed key joints (see Fig. 23) are not necessary, as the joints are not exposed to view and because of the stiffening effect of the plywood facings. The treatment at the edges shown at K is an alternative to the details at F, H and J. The outer veneer only of the 3-ply facing covers the framing. This veneer may be highly decorative. Its edges are vulnerable to damage, especially at the striking stile, and, as shown, they are bevelled to minimize this tendency. The detail of the glazed panel is similar to those shown in Fig. 24. The top of the skirting is assumed to be moulded with a fillet and curve similar to the architrave; this results in a mitre and a satisfactory finish (see C).

The solid or laminated core type of flush door is shown at D and detailed at H. The laminæ are only $\frac{5}{16}$-in. wide and this detail therefore shows an application of laminboard (see p. 103). Blockboards (the laminæ are not greater than 1-in. wide, see p. 103) are also used as cores. The tongued edging slips are also dovetailed to receive the edges of the plywood facings which, after being glued, are sprung into position and pressed. In order to provide a contrast in colour, these slips may be of a different wood to the plywood facings. An effective appearance results if the section of the skirting is similar to the outer splay of the simple architrave; the resulting mitres are shown in the elevation at D. This is a good type of door, although heavy, and is more highly fire-resisting and sound-insulating than the skeleton framed variety (see p. 51).

Another form of fire-resisting and sound-insulating door is shown at E and detailed at J, compressed granulated cork being filled between the members of the skeleton frame (see p. 51). A lock block is shown at each side, and therefore either stile may be hung.

The timbers used in the manufacture of mass-produced flush doors include alder, beech, birch, Columbian or Oregon pine, Canadian red pine and gaboon. These are usually painted or stained. The outer veneers of the plywood facings of superior doors are generally of hardwood, of which there is a large variety used. They are often left in their natural colours, the decorative effect depending upon the grain and texture of the woods. Oak, walnut, mahogany, Indian silver greywood, sycamore, Indian laurel, black bean and ash are a few of the many hardwoods used for this purpose. An outer veneer may consist of a single sheet or it may comprise several inlaid pieces arranged in squares or rectangles. Cross-bandings (narrow inlaid strips) of a dark wood—such as black bean—are effectively used to divide lighter coloured woods into panels.

## WINDOWS

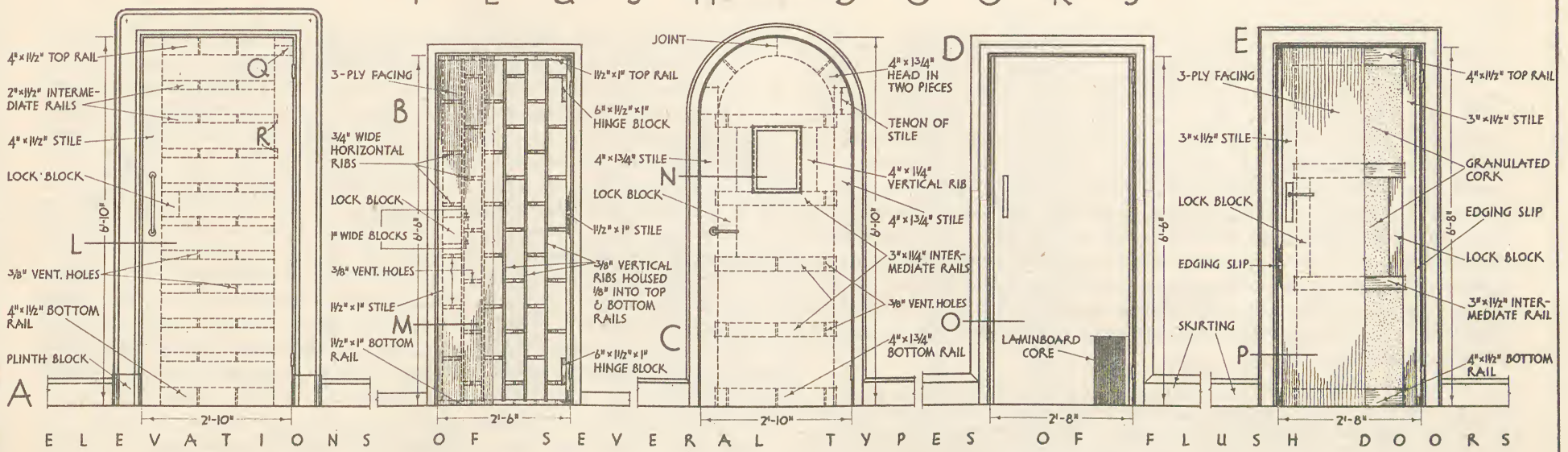
A description of casements, dead lights, window with cased frame and vertical sliding sashes, window with pivoted sash and window with horizontal sliding sash is given on pp. 107-122, Vol. I. The following types are dealt with here: (*a*) Window having a semicircular headed cased frame and vertical sliding sashes, (*b*) three-light windows and (*c*) metal windows.

(*a*) Window with Semicircular Headed Cased Frame and Vertical Sliding Sashes (see Fig. 26).—The elevation, section and plan at A, B and C show a large window of this type fixed in an opening in a brick wall with stone dressings.

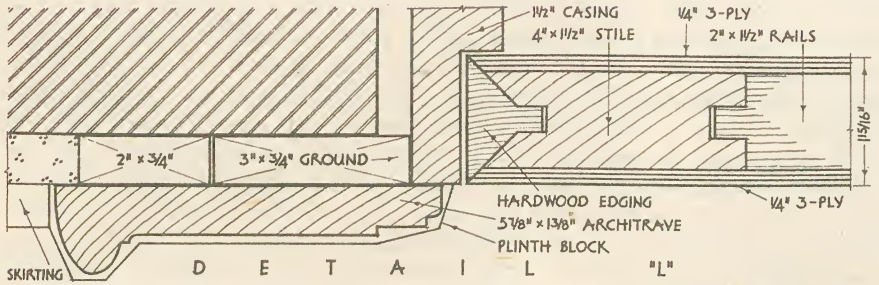
With the exception of the head, the construction of the frame is similar to that described on pp. 113 and 114, illustrated in Figs. 60 and 61, Vol. I. The usual construction of a semicircular head is shown here at E, F and R, Fig. 26. The soffit lining is built-up in two thicknesses of 2-in. thick segments, divided by the parting bead, sawn to the required curve and glued and screwed together to overlap with joints normal to the curve. The inner and outer linings are glued and blocked to the soffit lining, the tongues and grooves (indicated by broken lines at R) being often omitted because of the thickness of the head, which exceeds that of the tongued pulley stiles. In lieu of the tongued edges shown, the pulley stiles are sometimes square edged; the edges are well painted to protect them before the stiles are nailed to the linings; the inner lining is slightly

[1] By courtesy of the British Standards Institution.

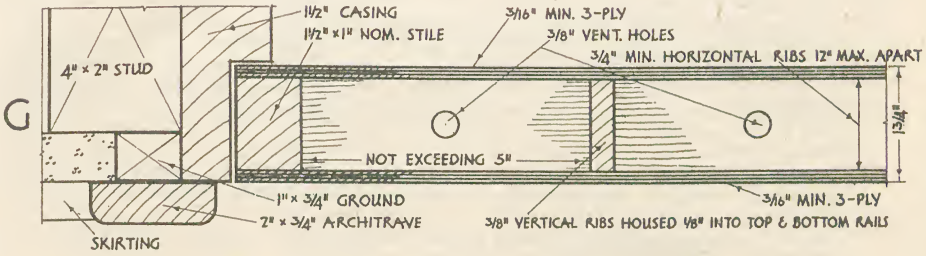
# FLUSH DOORS



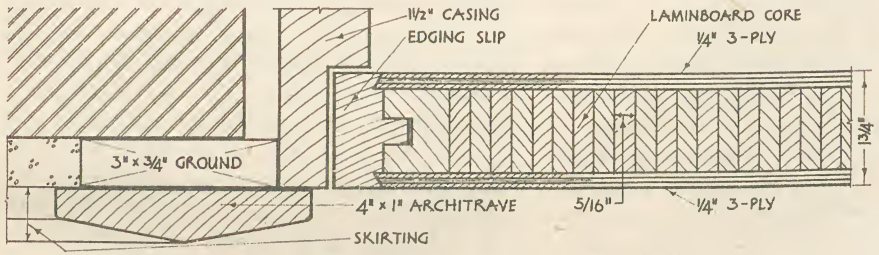

ELEVATIONS OF SEVERAL TYPES OF FLUSH DOORS



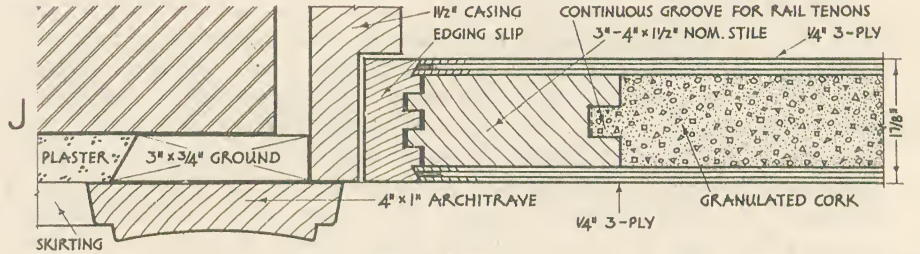

DETAIL "L"



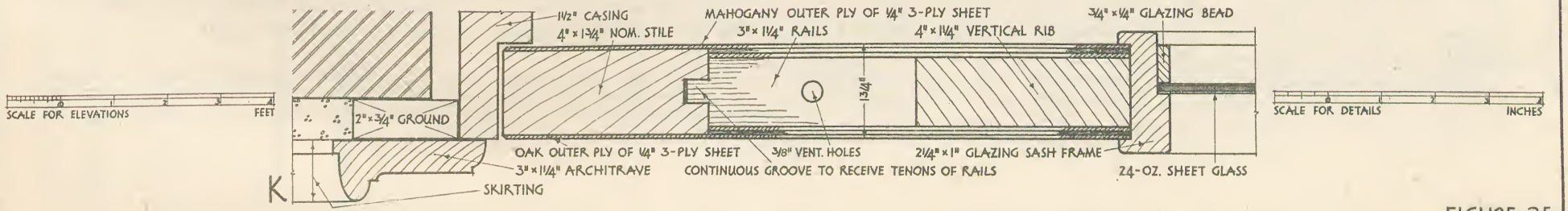

DETAIL "M"




DETAIL "O"




DETAIL "P"




DETAIL "N"

FIGURE 25

rebated to receive the square edge of the stile and the outer edge of the latter is butt jointed and nailed to the outer lining. The upper ends of the pulley stiles are rebated and continued above the springing line to receive the lower ends of the head. The members are glued, well screwed from the back and blocked. Attention is drawn to the projection of the end of the curved head beyond the face of the pulley stile (see E). The purpose of this ½-in. stop is to restrict the upward run of the bottom sash and thus prevent it being jammed in the head ; it also prevents damage to the glass in the upper sash which may otherwise occur if the latter was forced tightly against the crown of the frame. The joints between the segments of the inner and outer linings are either tongued and grooved or cross tongued and grooved ; G shows a t. and g. springing joint in an inner lining ; the ends of the wider outer linings are similarly shaped, although the tongues are usually stopped short of the outer edge. The parting slip is suspended from the block shown at E.

An alternative curved soffit lining consists of a *veneer* (a thin sheet of wood, ⅛ to ¼-in. thick and a little wider than the finished soffit, planed on the face and prepared on the back with a toothing plane to surface it for glue), shaped over a *cylinder* and backed with *staves* (narrow pieces of wood slightly longer than the width of the soffit, 1 to 1½-in. wide and of equal thickness). The cylinder resembles a centre consisting of two built-up ribs, cut to the semicircular curve and closely lagged ; the back of the laggings is planed to a true curve of the required radius of the soffit. The veneer, face downwards, is secured at one end of the cylinder by a stave placed across it and screwed at both ends to the cylinder. The veneer is gradually bent over the cylinder, temporary staves being screwed across it to the cylinder at required intervals and at the opposite end. The whole of the back is now staved. Commencing at one end, the staves are glued to the veneer and to each other, and the ends, having been previously holed, are screwed temporarily to the cylinder. After the glue has thoroughly dried the veneered soffit is removed by unscrewing the ends of the staves, sawn to the required width and then screwed to the pulley stile as explained above. Before bending, hardwood veneers must be softened by steaming or by soaking in hot water ; softwood veneers can usually be bent dry.

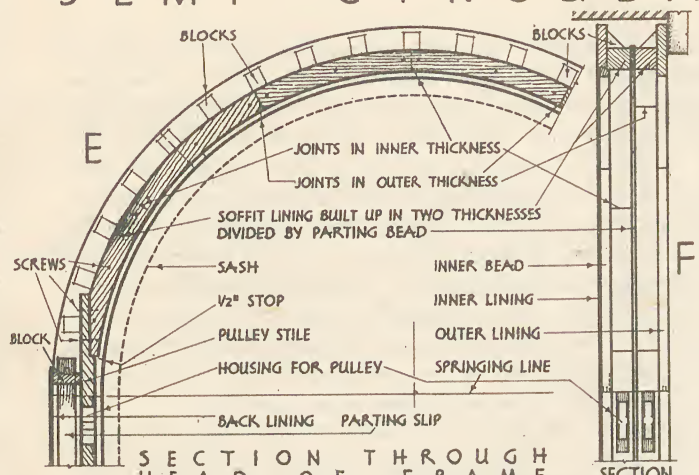
Details of the top sash are shown at J and K. The sash, indicated by thick lines, has a semicircular head in one thickness which comprises two segments jointed at the crown and either at the springing O or, preferably, above it (especially if the pulleys are fixed just below the springing line) as indicated by the broken radial line at P. These butt joints are formed with *handrail bolts*, so called because they are invariably used to ensure tight fitting joints between portions of handrails ; they are also applied more widely. A handrail bolt is illustrated at Q, and consists of a square nut, a round slotted nut (as it has five or six shallow slots cut in its outer edge) and a washer, in addition to the bolt which has screwed ends. Details showing the application of this bolt at the crown joint in the sash are shown at L and M. A hole, slightly larger than the diameter of the shank, is bored centrally in each of the adjacent ends of the segments for the bolt. Two holes are also made from the top, one just sufficiently large to receive the square nut and the other for the washer and slotted nut. The joint is formed in the following manner : The square nut is placed in its hole and the bolt is inserted and screwed on to the nut until half of its length only projects. After gluing the ends, the washer and slotted nut are put into the hole in the other segment and the free end of the bolt is slipped into the drilled hole. The bolt is next tightened by means of a *handrail punch* (a chisel with its edged end slightly curved) or similar tool, which is engaged in the notches of the slotted nut in turn as it is caused to rotate, and this is continued until the ends of the segments are brought together and a tight joint ensues. The joint is strengthened by means of a *cross tongue*[1] which is grooved into the ends at the rebate side ; this prevents the pieces of timber from twisting. Two or three small ($\frac{5}{16}$-in. diameter) hardwood dowels serve the same purpose. A sketch of the springing joint with projecting bolt and tongue is shown at H.

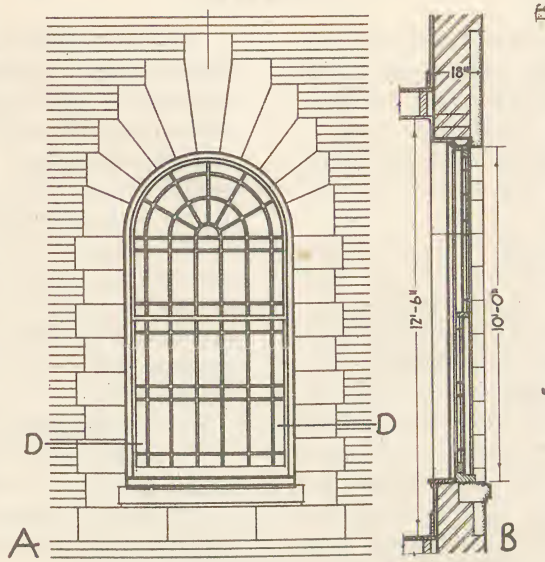
Enlarged details at the head, jamb and sill are shown at R, S and T. These are self-explanatory, especially if those in Figs. 60 and 61, Vol. I, have been studied. It will be observed that : (1) Thick pulley stiles are employed (which take most of the weight of the large sashes), (2) the pulley stiles and soffit lining are slightly rebated to receive the inner beads (this ensures the correct re-fixing of the beads and a free run for the bottom sash on being replaced after cord replacements), (3) the outside of the groove for the water bar at T is in line with the inside of the outer lining (and thus water passing along a defective bedding joint will only affect a small portion of the wood sill), (4) a deeper draught bead than the inner beads is employed to enable the lower sash to be raised slightly to permit of ventilation at the meeting rails (if the width of the draught bead is still further increased, the bottom rail of the sash should be correspondingly deeper to ensure, as shown, the margin between the top of the sash and the bead being equal to those shown at R and S) and (5) this draught bead and the bottom rail are bevelled to prevent vibration of the sash by ensuring a tight fit between it and the parting bead (the slight clearance shown between the sashes, outer lining and beads is to allow for three coats of paint).

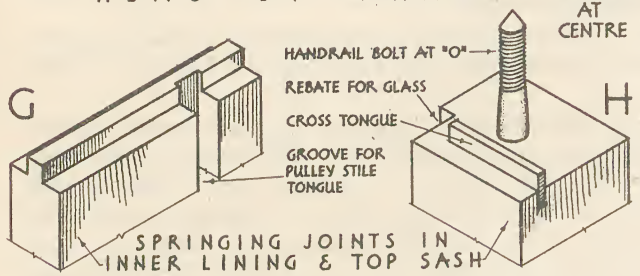
*Segmental-headed Windows.*—The heads of the frame and sash of a window curved to the form of a segment having a relatively large rise may be constructed as described above, the number of joints depending upon the span and the amount of the rise. If, however, the rise is small, it is usual to provide the window with a square head, as indicated by broken lines at B, Fig. 27. The construction of the head, with its inner, outer and soffit linings, is as shown in Figs. 60 and 61, Vol. I, except that the *outer* lining of the head is of wider stuff and swept to the curve of the segment. Thus, whereas the external appearance of the head is segmental (parallel to the intrados of the arch), that internally is the same as a square head above which a lintel and not an arch is provided to support the wall over the opening. The head of the sash is as shown at E, Fig. 27, the lower edge of the top rail being shaped to the sweep of the outer lining. This rail is tenoned and wedged to the stile of the sash as indicated.

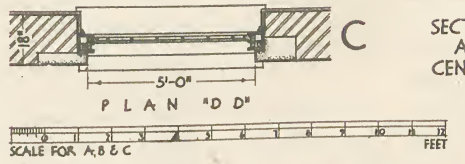
[1] Cross tongues are about ⅛-in thick and so called because they are cut across the grain of the squared end of the board from which they are made. Cross tongues are stronger than *feather tongues* (used for similar purposes), as the latter are cut diagonally across the grain.

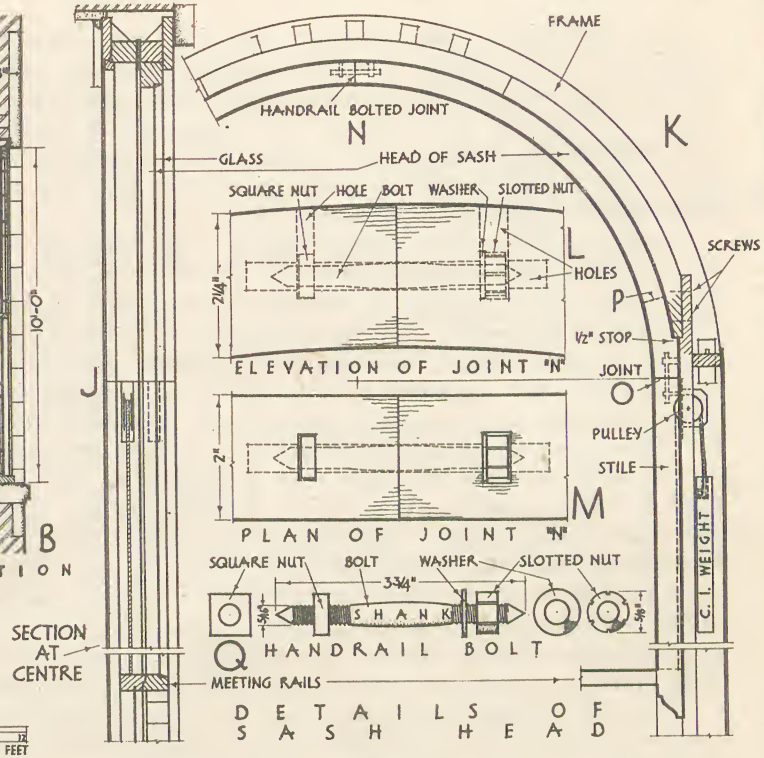
# SEMI-CIRCULAR HEADED CASED WINDOW

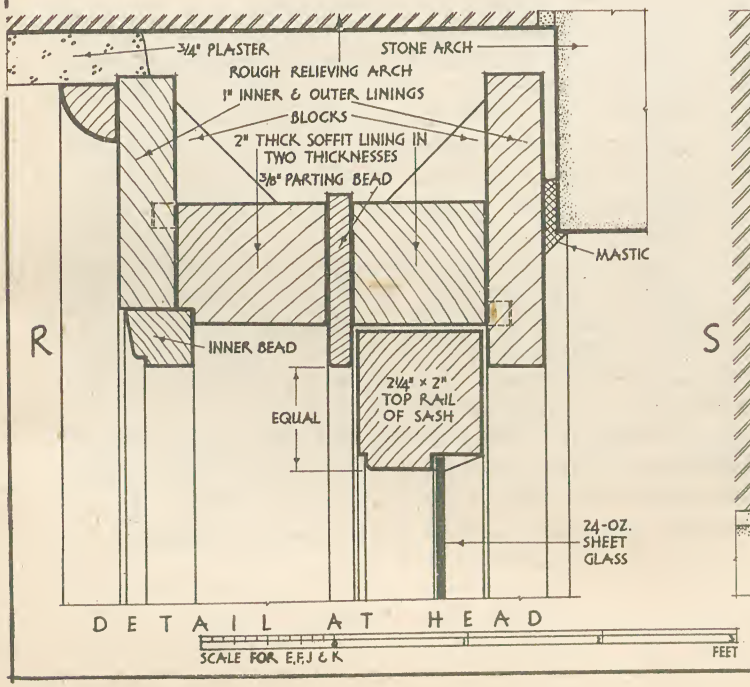


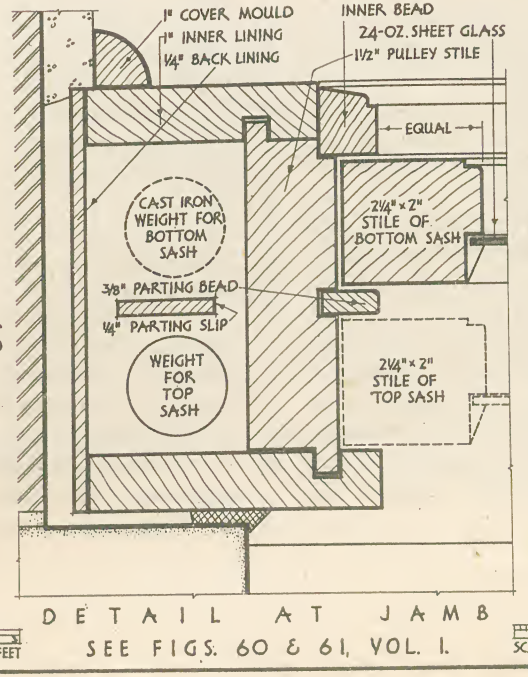



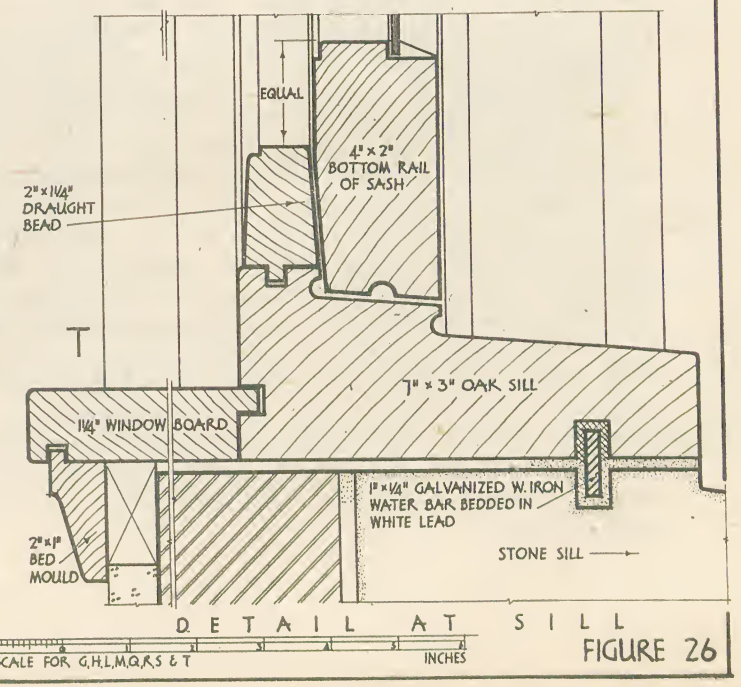





EQUAL
4" x 2" BOTTOM RAIL OF SASH
2" x 1¼" DRAUGHT BEAD
T
7" x 3" OAK SILL
1¼" WINDOW BOARD
1" x ¼" GALVANIZED W. IRON WATER BAR BEDDED IN WHITE LEAD
2" x 1" BED MOULD
STONE SILL
DETAIL AT SILL
SCALE FOR G, H, L, M, Q, R, S & T
INCHES

SEE FIGS. 60 & 61, VOL. I.

FIGURE 26

(*b*) THREE-LIGHT CASED WINDOWS (see Fig. 27).—Like casements (see B, Fig. 56, Vol. I), windows with vertical sliding sashes may each consist of two or more lights or pairs of sashes separated by vertical members, called mullions. A wide opening may be divided into three lights, and as shown at A, B and C, it is usual to make the central pair of sashes wider than the adjacent side lights. In some such windows all of the sashes are made to open, and others have fixed side lights with opening central sashes.

In the part elevation at A, the side lights are fixed, being screwed to the frame, and the central pair of sashes only are free to move. As the mullions are solid (see detail at G) the weights for the central sashes must be accommodated in the frame at the jambs. Four *pairs* of pulleys are therefore required, four pulleys for each of the top and bottom hung sashes. At A the weights for the bottom central sash are shown in full to make them conspicuous, and portions of the sash cords are indicated by broken lines. The cords from the sashes to the weights pass over the pulleys fixed at the top of the mullions and those secured to the head of the pulley stiles at the jambs. The pulleys must be fixed as high as possible, and to permit of this a portion is removed from the top of each pulley cover or face plate. The cords between the pulleys pass immediately under the head of the frame at the side lights, those fixed to the top sash being accommodated in grooves in the top rails of the two upper side sashes, and the other two cords are hidden from view when, as shown at D, grooved cover beads are screwed (in order that they may be removed readily when broken cords require attention) to the heads of the side lights.

The solid mullions, which vary from 1½ to 2-in. in thickness, are double tongued or housed to the outer lining (see G), rebated to receive the inner beads and grooved for the parting beads. The side boxes are constructed in the usual manner, *i.e.*, the 1¼-in. pulley stile is tongued (see p. 70) to the 1-in. inner and outer linings, a ¼-in. back lining (often omitted) completes the box, and a ¼-in. parting slip is provided to separate the weights (see F).

The head is usually solid (see D) with an outer lining (or it is the full width of the frame and an outer bead is planted on). The mullions (G) are tenoned and wedged to the head, and the pulley stiles (F) are housed into the latter.

An alternative arrangement for hanging the central sashes consists of the provision of cased or framed mullions in lieu of the solid mullions, and solid 3-in. thick jamb posts instead of the built-up side boxes. The mullions resemble that shown at J, except that the internal width need only be 2-in. and the thickness of the stiles next to the fixed side lights may be reduced to 1-in.

The whole of the sashes of the window at B are made to open. The boxes at the jambs are as shown at F. The mullions are double boxed or cased, *i.e.*, arranged to accommodate two sets of weights as shown at B and detailed at H. In each mullion the weights of the central sashes are separated from those of the side sashes by a ½-in. dividing strip, and the top and bottom weights of each sash are separated by the usual ¼-in. parting slip. The finished width of the mullions is 8-in,

The part elevation of the window at C also shows each light to consist of sliding sashes. A detail of one of the cased mullions is given at J. It accommodates two large weights, one to balance the sum of half of the weights of the central and side bottom sashes and the other to counterbalance half of the adjacent top sashes.[1] A pulley is fixed at the top of each weight, and four pulleys are screwed to, and near the head of, the pulley stiles of each mullion—one for each of the adjacent top and bottom sashes. Each cord passes under the weight pulley, over the two mullion pulleys and fixed to both of the central and side top (or bottom) sashes (see broken lines at C). Cylindrical cast iron weights are preferred, but if heavy weights are unobtainable from stock, specially cast lead weights are employed. This is an alternative arrangement for hanging the sashes to that shown at B and H and results in a reduction of 2-in. in the width of the mullions. The construction of the side boxes is as shown at F.

If brick or stone mullions are employed, it is usual for each light to consist of a separate cased frame of normal construction (see Fig. 60, Vol. I), although types B and C are sometimes preferred.

(*c*) METAL WINDOWS.—These are included in this chapter, as many windows of this type are used in conjunction with wood frames and are fixed to the latter by the joiner.

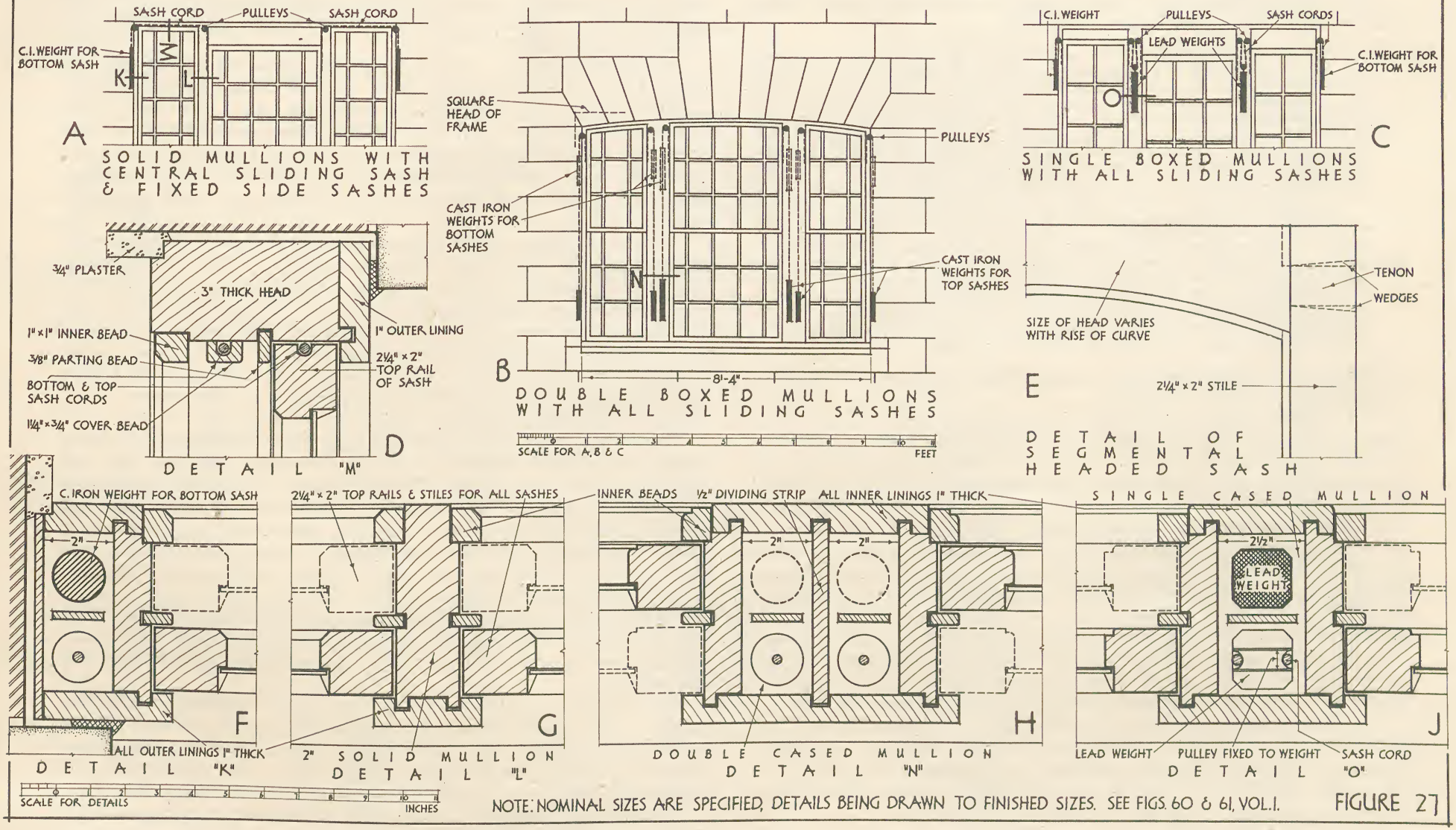
The metals used in the manufacture of these windows are mild steel, bronze and other alloys. Undoubtedly bronze windows are the best, as they are rust-proof and are finished with a good surface of a pleasing colour which, if kept clean, improves with age. They are, however, relatively expensive, and for this reason their use is restricted. Since 1920 there has been a big demand for steel windows in lieu of wood casements. There are several forms, including fixed lights, casements opening outwards, inwards and pivoted, etc.

Most manufacturers produce what is known as the " standard metal window," made in several sizes from steel of the same thickness rolled to a common section. They have been used extensively for houses and small buildings, and it is this window, in its simplest form, which has been illustrated in Fig. 28. A fixed light consists of a frame only, and a casement has a sash which is attached to the frame by means of two hinges. The details show that the *frame and sash are of ⅛-in. thick metal and their sections are identical in size and shape*. They are of Z-section, 1-in. deep with ¾-in. wide flanges, one of the latter having a slight projection beyond the web to allow the sash and frame to overlap ¼-in. both internally and externally. The horizontal and vertical members of the frame and sash are solidly welded at the corners. Sashes are made with and without ¾-in. by ¾-in. by ⅛-in. glazing bars or astragals of T-section, the bars being threaded and locked at the intersections. That at A is of the horizontal bar type, for, unlike the sash at E, vertical bars are not provided.

The hinges usually preferred are of the extension type (see Fig. 59, Vol. I), as, when fully extended, the 4 to 5-in. clearance resulting between the sash and the frame enables the outside of the glass to be cleaned from the inside. These

[1] See note on p. 118, Vol. I, regarding the determination of weights for sashes.

# THREE LIGHT CASED WINDOWS




NOTE: NOMINAL SIZES ARE SPECIFIED, DETAILS BEING DRAWN TO FINISHED SIZES. SEE FIGS. 60 & 61, VOL. I.

FIGURE 27

steel hinges are provided at the top and bottom of a sash (see A, E, G, H and K, Fig. 28), the fixed arm being riveted or welded to the frame and the moving arm (rotating on a hard-wearing pin of phosphor-bronze or stainless steel) is fixed to the sash. The sketch at M shows the position of the partially extended hinge relative to the frame and sash.

The sash is provided with a casement fastener, or *two-point handle*, and a casement stay. These are of bronze or gunmetal.

A two-point handle is shown in the two small-scale elevations at A and E and the plan at N. It is mounted on a pin attached to a back plate which is riveted or welded to the inner flange of the sash, and is so called because of the points formed at the nose by the notches (see N). As shown, a thin bronze *striking plate* (about 1-in. by $\frac{3}{8}$-in.) is secured to the inner flange of the frame. Its object is to prevent the nose of the handle contacting the flange and damaging the paint. When the position of the nose is as shown, a tight fit between the sash and frame should result; the clearance shown is exaggerated to make the details clear. As noted, ventilation can be afforded by engaging the flange of the frame (and striking plate) in either notch "1" or "2"; an opening up to 1-in. in width can thus be maintained.

Additional ventilation can, of course, be obtained by applying the casement stay. This may be a peg stay (see D, Fig. 59, Vol. I), when a pin plate or bracket is fixed to the inner flange of the horizontal member of the frame. The objection to this stay is the damage to glass which may be caused if the sash is blown violently against the wall in the event of the window being left open without the pin engaging in one of the holes in the bar. A better form is the *sliding stay* (consisting of a horizontal arm fixed to the sash which slides through a pivoted fitting at the free end of a rotating bracket fixed to the frame), as this, whilst permitting the sash to be maintained at any angle up to 90°, always keeps it under restraint.

FIXING.—The metal frame may be fixed direct to the wall, or it may be screwed to a wood frame or surround.

The window shown at A, B and C, and detailed at G, H, J and K, is fixed direct. Eight ($\frac{5}{16}$-in. diameter) countersunk holes are provided in the web of the frame to receive the fixing screws (see A). If it is to be fixed to masonry, terra-cotta or concrete, $\frac{1}{2}$ or $\frac{5}{8}$-in. diameter holes are cut in the jambs, head and sill opposite the holes in the frame. These are preferably plugged with lead, although hardwood plugs or rawlplugs are more often used. The window is then placed in correct position and the frame is screwed to the plugs. The frame is finally grouted in and pointed with cement mortar, or bedded and pointed with mastic. The details at G and H shows these fixings. As mentioned above, the jambs may be plugged and screwed in this manner. The details at J and K show an alternative method of fixing the frame by means of 4-in. by $\frac{5}{8}$-in. by $\frac{1}{4}$ or $\frac{1}{8}$-in. lugs (provided by the manufacturers) which are bent-up 1-in. Holes are cut in the jambs of the wall at the correct position, and the lugs are inserted and firmly cemented in. The frame is secured to the lugs by $\frac{1}{4}$-in. diameter fixing bolts.

The above method conforms to the best practice, as windows should never be fixed in position until the roughest work has been completed. Otherwise damage may be caused, not only superficially from daubs of set mortar, etc., but to distortion of sashes which can only be straightened with difficulty and often cause subsequent leakage between them and the frames.

It is, however, the usual practice in cheaper work to build-in the metal windows as the construction of the walls proceeds, especially if the walls are of brick. Typical fixing details of a built-in frame are shown at J and K, already referred to. The lugs are bolted to the frame and the window is placed in position. It is kept level and plumb as the building of the wall proceeds, and the lugs are securely built-in with mortar. The lugs are shown bedded in the horizontal joints (see A, J and K). Cutting of the bricks, stone, etc., must be resorted to when the joints do not coincide with the lugs. Lugs are also built-in at brick heads and sills.

A vulnerable part of a metal window which opens outwards is the outer flange of the top horizontal sash member where it contacts the frame. In an exposed position water may enter here even if the sash is tight fitting. It is advisable, therefore, to throat the underside of the head and adopt wide external jambs by fixing the windows well away from and not nearer than 2-in. to the face of the wall. The more elaborate type of window has a metal projecting strip, fixed to the top of the frame just above the sash, which serves as a protection.

Criticism is directed against metal windows fixed direct in certain types of buildings because of the mean appearance presented by the narrow frames. This is emphasized if the colour of the painted windows contrasts with that of the adjacent walling. Hence, as shown at D, E and F and detailed at L, N, O, P and Q, metal windows are often fixed in wood frames. The latter are rebated, or double rebated as shown, to receive the metal frames. *The steel frame is bedded in mastic, and this must be well done to prevent the entrance of water between the two frames.* The metal frame is then screwed to the surround, $\frac{5}{16}$-in. diameter holes being provided in the former for this purpose.

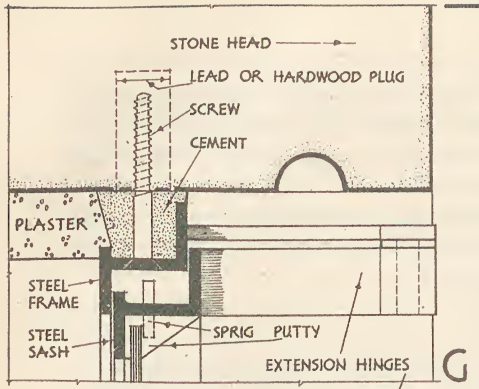
Putty is used for glazing standard metal windows. Ordinary putty (whiting ground in raw linseed oil) alone is useless for this purpose, as it will "run," and gold size is added to it to enable it to set. Small metal dowels or sprigs ($\frac{1}{8}$-in. diameter) are sometimes used to retain temporarily the panes of glass until the putty has set (see G, H and N). Holes ($\frac{1}{8}$-in. diameter) are provided to receive these. Alternatively, thin metal clips provided at each corner of a pane and fixed to the sash serve the same purpose. These are bent against the glass before the puttying is completed.

Metal windows quickly corrode unless suitably treated. Spraying them with zinc after the surface has been thoroughly cleaned and roughened by sand-blasting is one of several rust-proofing processes which has been adopted on a large scale.

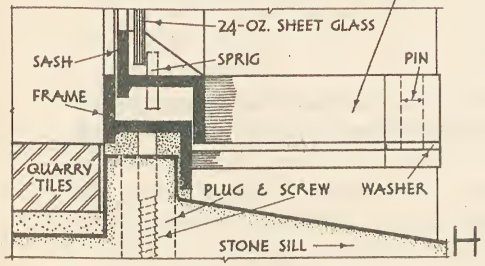
Steel windows compare favourably with wood casements in excluding weather. Unlike those made of wood, metal windows are not, of course, affected by atmospheric changes and consequently they do not jam (see p. 78), a defect common to certain wood casements due to swelling. Steel windows are very durable, especially if rust-proofed. The standard types are economical in price.

Perhaps the chief demerit of the standard steel window is its poor appearance, due to the small size of the frame and sash members. If, in order to counteract

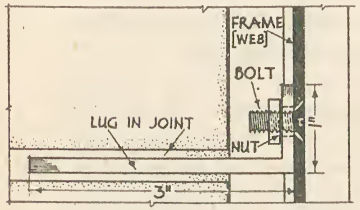
# METAL WINDOWS



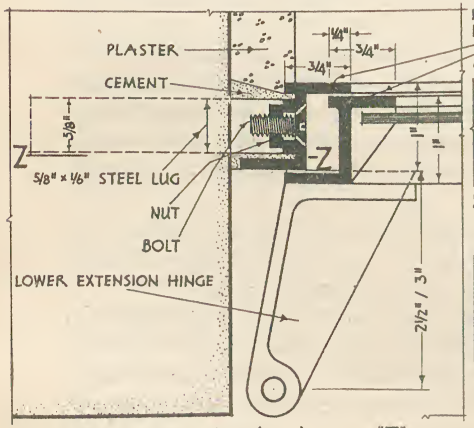

DETAIL "R"




DETAIL "S"

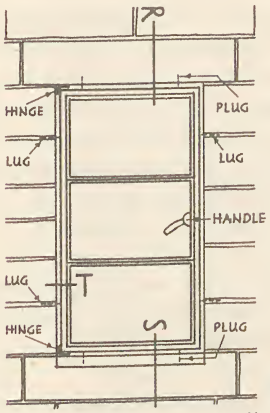



SECTION "Z Z"

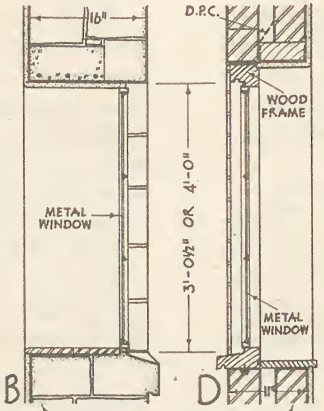



DETAIL "T"

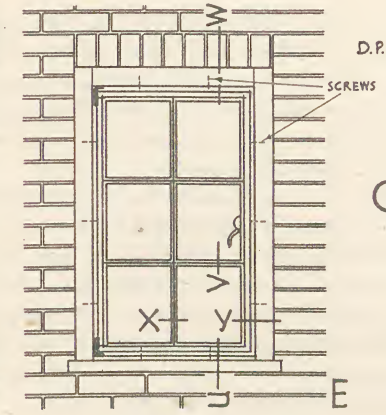
K



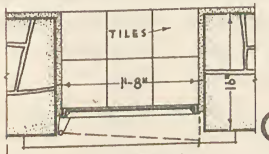

ELEVATION




SECTIONS "R S" & "U W"

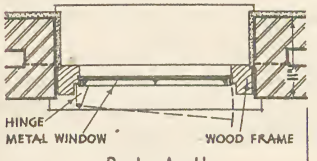



ELEVATION

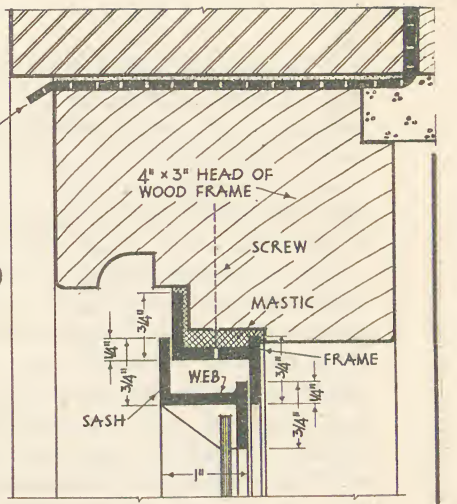



PLAN
METAL WINDOW WITHOUT WOOD FRAME

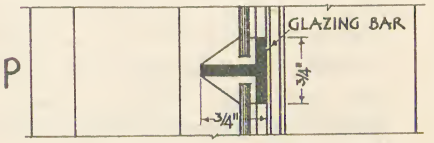
STANDARD HEIGHTS: 2'0 13/16", 3'-0½", 4'-0" ETC.
STANDARD WIDTHS: 11" & 1'-8".
UNITS OF STANDARD SIZE CAN BE JOINED TO FORM COMPOSITE WINDOWS.




PLAN
METAL WINDOW IN WOOD FRAME

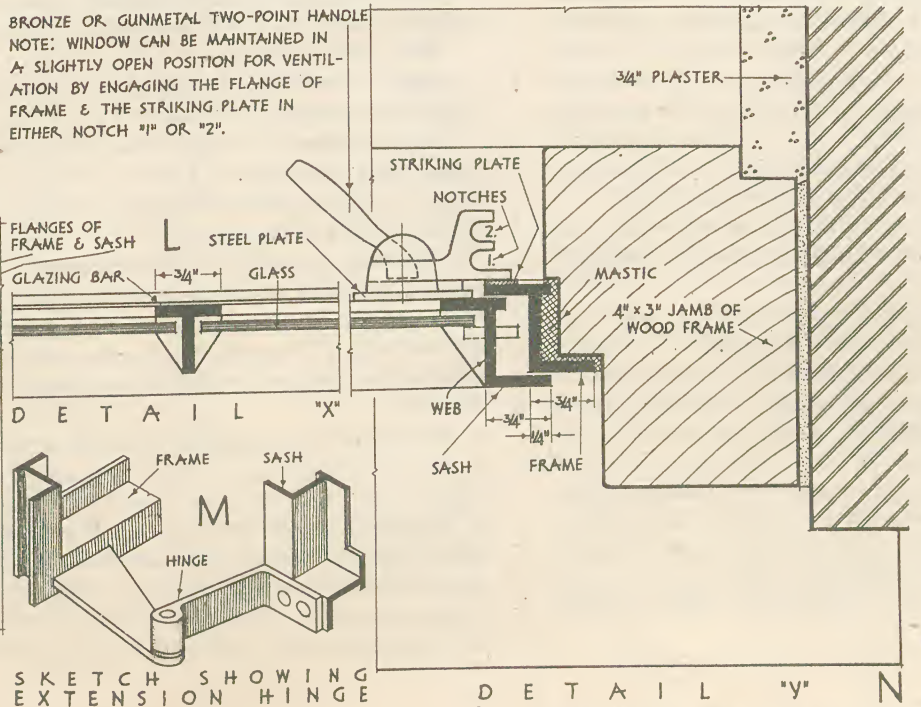



DETAIL "W"




DETAIL "V"

BRONZE OR GUNMETAL TWO-POINT HANDLE
NOTE: WINDOW CAN BE MAINTAINED IN A SLIGHTLY OPEN POSITION FOR VENTILATION BY ENGAGING THE FLANGE OF FRAME & THE STRIKING PLATE IN EITHER NOTCH "1" OR "2".




DETAIL "y"

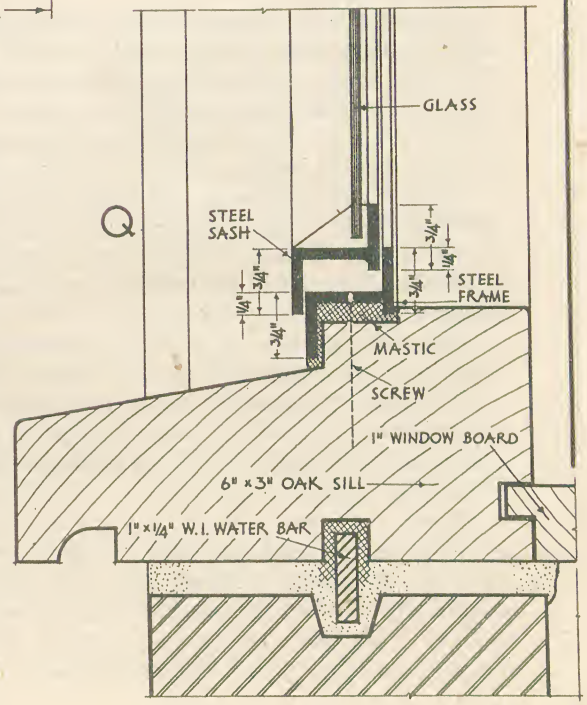
N




DETAIL "X"




SKETCH SHOWING EXTENSION HINGE




DETAIL "U"

NOTE: THE SECTION & SIZE OF BOTH FRAME & SASH ARE IDENTICAL & THE THICKNESS OF THE MILD STEEL IS 1/8".

SCALE FOR DETAILS — INCHES
SCALE FOR A,B,C,D,E & F — FEET

FIGURE 28

this, the metal windows are fixed in wood frames the total cost exceeds that of ordinary wood casements with frames. Unless steel windows have been rust-proofed, they corrode very rapidly and assume an ugly appearance because of the resulting damaged paintwork. Improper fixing of the glass will cause the lower rail of the sash to jam on the bottom of the frame, and a strained sash will result in the development of leaks between it and the frame.

Some standard heights and widths of metal windows are given in Fig. 28. These are the overall sizes of the frames, as indicated in B and C. These units can be coupled together to form composite windows of large size having metal mullions, transomes, etc. Such a window may also consist of several standard metal frames and sashes fixed in a wood surround with wood mullions and, if required, wood transomes. There are also special types of metal windows suitable for schools, hospitals, commercial buildings, etc. These, together with leaded lights and metal doors, are detailed in Vol. IV.

## STAIRS

The materials used in the construction of stairs are stone, steel, wrought iron, cast iron, reinforced concrete, reinforced brickwork, and wood. The former type has been detailed in Chapter III, Vol. II, and the latter will be considered here.

A stair is a set of steps leading from one floor to another. A continuous series of steps forms a flight, and there may be two or more flights, separated by flat portions called landings, between two floors. A stair, together with the part of the building accommodating it, is known as the staircase. The horizontal portion of a step, called a tread, is usually connected to a vertical riser and these are supported by inclined boards termed strings.

TERMS.—The following definitions of terms are arranged in alphabetical order for ready reference. Some of them are amplified in later paragraphs.

*Apron, Apron Lining or Fascia* (see G, Fig. 32, and C, G, M and N, Fig. 36) is a board which covers the trimmer, etc. joist of a landing, providing a suitable finish to it and the adjacent plaster.

*Balusters* (see Figs. 29, 32, 33, 34, 36 and 38) are short vertical bars which support the handrail and protect the open side or sides of a stair.

*Balustrade or Banister.*—An *open* balustrade comprises the balusters, handrail, string and newels (if any) (see Figs. 29, 32, 33, 34 and 36). A *solid* balustrade consists of panelling in lieu of balusters (see M, Fig. 29, Fig. 35, H and O, Fig. 36 and Fig. 37).

*Bearers.*—Inclined 4-in. by 2-in. or 4-in. by 3-in. members which support the steps and to which the laths of a plastered soffit are nailed. Those which serve as intermediate supports are also called *carriage-pieces, rough carriages, rough strings* (as they are not dressed) or *spring-trees* (see Figs. 30, 31, 32, 36 and 38). The short supporting members placed immediately below winders (see p. 80 and Fig. 38) are also called bearers.

*Blocks* are fixed to the upper edges of bearers and provide additional support to the treads (see Fig. 38). The term is also applied to the small pieces of wood of triangular section which are glued to the inner angles between treads and risers or strings (see F, Fig. 30, Figs. 31, 32, etc.).

*Brackets or Rough Brackets* are more commonly employed and serve the same purpose as blocks, the 1-in. thick pieces of wood being nailed alternately to the sides of the bearers (see Figs. 30, 31, 32 and 36).

*Bull-nosed Step.*—See " Steps."

*Caps.*—See " Newels."

*Cappings* are cover mouldings planted on the upper edges of strings (see F, Fig. 32, and J and K, Fig. 34), handrails (see D, Fig. 35), panelling (see B and C, Fig. 35) and newels.

*Carriages.*—See " Bearers."

*Commode Step.*—See " Steps."

*Cover Fillets* are small members fixed to the underside of outer strings and trimmers to provide a satisfactory finish to the adjacent plaster (see G, Fig. 32, N, Fig. 34 and M and N, Fig. 36).

*Curtail Step.*—See " Steps."

*Dancing or Balancing Steps.*—See " Steps."

*Dog-leg Stair.*—See p. 87.

*Drop.*—See " Newels."

*Easing* is a curved upper portion connecting two strings of different inclinations or a string with a skirting (see C, Fig. 30 and B and G, Fig. 38).

*Flier.*—See " Steps."

*Flight.*—A continuous set of steps extending from floor to floor, or floor to landing, or landing to landing.

*Going or Run* of a step is the horizontal distance between the faces of two consecutive risers (see F, Fig. 30, D, Fig. 31 and F, Fig. 32) and the going of a flight is the horizontal distance between the face of the bottom riser of the flight and that of the top riser.

*Handrails*, provided to afford assistance and a safeguard, are fixed at a convenient height to walls (see C, H and J, Fig. 30) or at the top of balustrades (see Figs. 32, 33, 34, 35, 36, 37 and F, Fig. 39); they should be of a satisfactory size and shape to enable them being easily grasped by the hand; of the many designs, the simple *mop-stick handrail* illustrated at F, Fig. 39, is one of the most effective.

*Headroom* is the height measured vertically from the line of nosings (see p. 79) to the lower outer edge of the apron (see C, Fig. 30) or to the soffit of a flight immediately above it. This should not be less than 6-ft. 6-in.

*Landing* is a platform between two flights provided to serve as a rest and, when required, to make effective provision for turning a stair; it also denotes the portion of the floor adjacent to the top of a stair. A *quarter-space landing* is one on which a quarter-turn has to be made between the end of one flight and the beginning of the next (see Figs. 29, 36 and 37). If the landing extends for

the combined width of both flights and a complete half-turn is necessary, it is known as a *half-space landing* (see Figs. 29, 32, 34 and 35).

*Line of Nosings* is that drawn to touch the projecting edges or nosings of the treads (see C, Fig. 30 and D, Fig. 31).

*Margin* is the portion of a close string (see p. 80) between its upper edge and the line of nosings (see D, Fig. 31). This term is also applied to the portions of treads and risers between the strings and the carpet or other covering.

*Newels or Newel Posts* (see Figs. 29, 32, 33, 34, 36, 37, 38 and 39) are substantial vertical members placed at the ends of flights to support the strings, handrails, trimmers and bearers. The upper moulded end is called the *cap* and the projecting lower end is known as a *drop*.

*Nosing* (see Figs. 30, 31, 32, etc.).—This is the front edge of a tread which projects beyond the face of the riser below it; it is also applied to the projecting upper member of an apron (see G, Fig. 32).

*Nosing Line* (see H, Fig. 31).—Drawn on a string for setting-out the steps and is the line set out at the required distance from, and parallel to, its upper edge along which is marked the intersecting points between the treads and vertical faces of the risers (see p. 84). It must not be confused with the "line of nosings" (see above) which is nearer to the upper edge.

*Open Well Stair.*—See p. 93.

*Pitch or Slope* is the angle between the line of nosings and the floor or landing.

*Pitch-board or Step-mould* is used for setting out the steps on the strings and is a thin wood triangular *templet* (*pattern* or *set square*). One of its sides is equal to the going, that at right angles to this is equal to the rise, and the remaining side gives the pitch of the stairs. That shown at E, Fig. 31, has, in addition, a "margin templet" (although its width is actually the distance between the edge of the string and the nosing line, see H), and a thin strip at right angles to it is maintained against the edge of the string and assists in ensuring accuracy in setting out. Two additional patterns, called a *tread templet* and a *riser templet* are required to set out the housings (see p. 84) of the treads and risers respectively (see F and G, Fig. 31); the width of the tread templet equals the thickness of the tread and that of the wedge, whilst the width of the riser templet is equal to the combined thickness of the riser and wedge. The application of these templets is shown at H (see also p. 84).

*Rise* of a step is the vertical distance between the tops of two consecutive treads (see F, Figs. 30 and 32), and the rise of a flight is the total height from floor to floor, or floor to landing, or landing to landing.

*Riser* is the front member of a step which is connected to the tread (see F, Fig. 30, etc.).

*Run.*—See "Going."

*Scotia* is a concave mould used to provide an additional finish to the nosing of a tread (see D, Fig. 31). A *scotia board* is cut from a relatively wide board and used at nosings of treads forming bull-nosed and similar rounded bottom steps (see Fig. 39).

*Soffit or Planceer* is the under surface of a stair which is often plastered (see C, Fig. 30, E, Fig. 32 and D, Fig. 36).

*Spandrel or Spandril* is the triangular surface, either plastered or panelled, between an outer string and the floor (see C, Fig. 32).

*Splayed Step.*—See "Steps."

*Stair.*—As stated on p. 78, this consists of a set of steps which leads from one floor to another. Stairs are classified as follows:—

(*a*) Straight Flight Stairs.

(*b*) Turning Stairs, including (i) quarter-turn, half-turn, three-quarter-turn and bifurcated, and (ii) newel and geometrical.

(a) *Straight Flight Stair* (see A, Fig. 29 and Fig. 30).—This continues throughout its entire length in one direction and may consist of a single flight only or two or more flights in its length which are separated by landings.

(b) (i) *Quarter-turn Stair* (see D, E, F and G, Fig. 29).—This type changes its direction either to the left or right, the turn being affected either by a quarter-space landing or by winders (see p. 80).

*Half-turn Stair* (see B, C, H, J, K and L, Fig. 29) has its direction reversed either by a half-space landing (as at B, C, H and K), or a quarter-space landing and winders, or two quarter-space landings and a short flight (as at J), or completely by winders (as at L), etc.

*Three-quarter-turn Stair* has its direction changed three times with its upper flight crossing the bottom one.

*Bifurcated Stair* (see M, Fig. 29) is a type common in public buildings in which it appears as a prominent feature. The bottom wide flight is divided at a landing into two narrower flights which branch off to the right and left. That shown is also known as a *double quarter-turn stair*; if each side flight is continued with an additional quarter-turn (as shown by broken lines at N), the complete structure is called a *double half-turn stair*.

(b) (ii) *Newel Stair* (see B, C, D, E, H, J and N, Fig. 29) has a newel at the foot and head of each flight of the stair. The newels are therefore a conspicuous feature.

*Geometrical or Continuous Stair* (see F, G, K, L and O, Fig. 29).—Both the strings and handrails are continuous and are set out in accordance with geometrical principles. A newel may, for reasons of design, be introduced at the bottom and top of such a stair, but is not an essential part of the construction. Those at G and L are also called *winding stairs*. Geometrical stairs, circular on plan and with the steps radiating from the centre, are called *circular* or *spiral* or *helical* stairs; the wall string of a circular stair may be octagonal on plan as an alternative to the more expensive circular form. An *elliptical stair* is of this type, the plan of its outer string being in the form of an ellipse with its wall string parallel to it.

Stairs in class (*b*) include the *dog-leg* (see B and H, Fig. 29 and Figs. 32, 34 and 35) and *open well* (see C, J, K and L, Fig. 29 and Figs. 36 and 37).

*Staircase.*—This, as previously stated, includes a stair and the part of the building which encloses it.

*Stairway* is the opening or space occupied by the stair.

*Step*.—As applied here, it consists of a tread and riser [1] supported by strings. The following are the types of step employed: *Bull-nosed step* (see D, Fig. 29 and B, G, H and J, Fig. 39) is situated at the bottom of a flight, projects beyond the face of a newel or newels and has one or both ends rounded. A *commode step* (see step " 1 " at F and L, Fig. 29) has a curved riser and tread nosing. A *curtail*, *round* or *scroll step* (see F, Fig. 29, and C, K, L and M, Fig. 39) has one or both ends which are semicircular or spiral on plan. *Dancing* or *balancing steps* are winders (see below) which do not radiate from a common centre—two of this type are shown by broken lines at J′, Fig. 29. *Fliers* are those which are chiefly employed; they are of uniform width and are rectangular on plan, *i.e.*, all of those shown in Fig. 30; *diminished fliers* are those immediately adjacent to dancing steps, the width tapering towards the outer string (see J′, Fig. 29). A *splayed step* has one or both ends splayed as shown at A, Fig. 39. *Winders* are tapering steps, such as those which radiate from a point usually situated at the centre of a newel (see Fig. 38) and those which comprise a geometrical stair of the type shown at G and L, Fig. 29; because of its shape the central of three winders is called a *kite winder* (see also E, Fig. 29).

*Storey Rod*, *Post or Lath* is a dressed piece of wood, of approximately 1½-in. square, or 2-in. by ¾-in. scantling, sufficiently long to extend from floor to floor, on which is marked the exact floor to floor height of the part of the building which is to receive the stair; this rod is accurately and equally divided into the requisite number of steps and is then used in their setting out (see p. 84).

*Strings or Stringers* are the inclined members which support the steps. The following are some of the various forms: A *close* or *housed string* has both top and bottom edges parallel and the treads and risers are housed into it (see A, B, C, E, H and J, Fig. 29, and Figs. 30, 31, etc.). A *cut* or *open string* or *notch board* has its lower edge parallel to the pitch of the stair and its upper edge is cut or notched to receive the ends of the treads and risers (see D, F, G, K and L, Fig. 29 and N, Fig. 39). A *rough string* is a carriage-piece or bearer. Those fixed to walls are called *wall* or *inner strings* and are usually close strings; those on the outside are known as *outer strings* and may be of either the close or open type.

*Tread* is the horizontal member which forms the upper surface of a step (see F, Fig. 30, etc.).

*Walking Line* represents the average line of travel taken by a person when ascending or descending a stair, and is usually taken to be 1-ft. 6-in. from the centre of the handrail or newel (see D, Fig. 38).

*Well* or *Well-hole* is the space between the outer strings of the several flights of a stair (see C, J, K and L, Fig. 29 and E, Fig. 36) known as an *open well stair*.

*Winders*.—See " Steps."

Several of the above definitions will be amplified on the following pages.

[1] There have been several recent examples of principal stairs, constructed in office, etc., buildings, which resemble ladders in so far as risers have been omitted and the wood treads have been connected direct to steel strings.

ESSENTIAL REQUIREMENTS.—A well-designed stair should comply with the following requirements:—

1. It should be constructed of sound materials and workmanship, the treads and risers being properly tongued and grooved together, wedged, glue blocked and adequately supported. The strings should be well secured to walls, newels, trimmers, etc. A bearer or carriage, of sufficient size, should be provided if the stair is 3-ft. wide, with an additional bearer for every 15-in. in width, otherwise excessive deflection will occur and the stair will creak.

2. Its ascent should be relatively easy, and the proportions of treads and risers should conform to the rules stated on p. 82. The pitch must not exceed 45° if undue fatigue is to be avoided, and it should not be less than 25° in order to prevent a tedious ascent and the occupation of excessive space.

3. The whole of the risers must be of the same height, and the treads [1] should be of uniform width if accidents are to be avoided.

4. It should be well lighted, especially at turnings. A solid balustraded stair (see Figs. 35 and 37) requires a larger window than one with balusters, as the former offers a greater obstruction to light. When electricity is available, two-way switches (which enable a light to be controlled from two points) should be provided at the head and foot of the stair.

5. The maximum number of steps in a flight is preferably twelve; this is especially desirable for stairs used by invalids and the aged; stairs in public buildings should conform to this. Such limitation requires the provision of landings, but when space is restricted these cannot be provided and hence the number of steps often exceeds the desired maximum, as seen in Fig. 30.

What would otherwise be a half-space landing should not be divided into two quarter-space landings by a single riser; such an arrangement has been a frequent cause of accidents, especially to unaccustomed users.

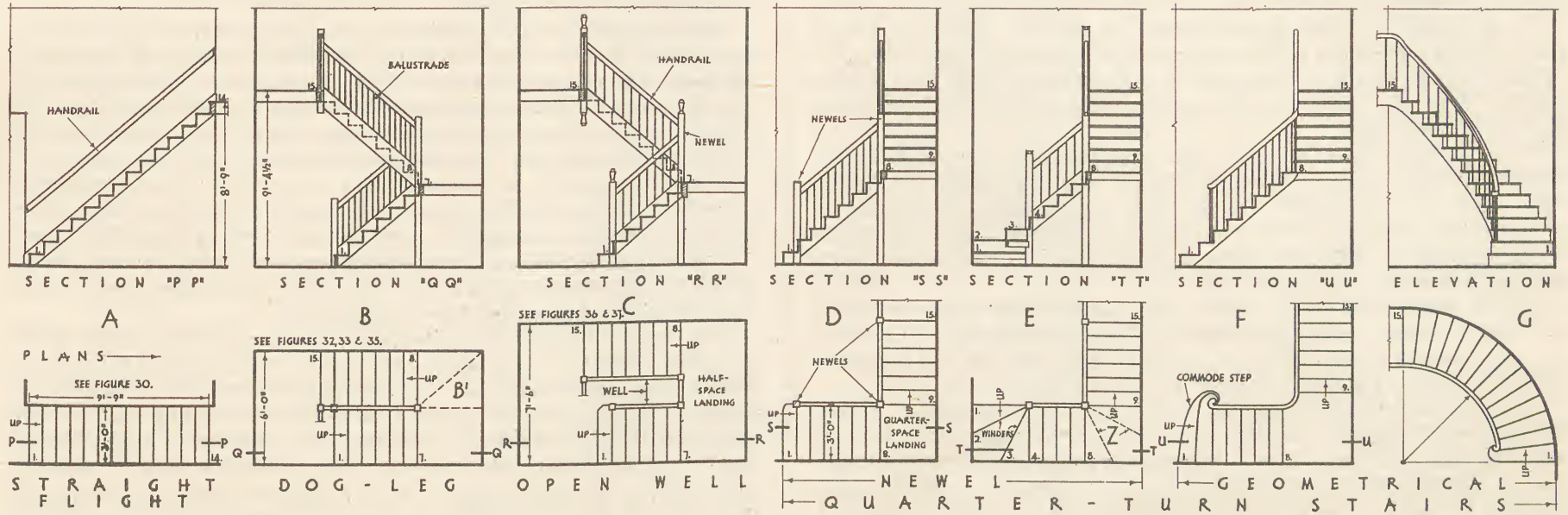
6. It must be of adequate width. A satisfactory width for the average-sized house is 3-ft. from wall to wall, or wall to centre of outer string. A narrower stair has a mean appearance and the conveyance of large pieces of furniture, luggage, etc., is likely to damage its balustrade and walls. The width of landings should be at least equal to that of the steps; an increased width is preferable, as the appearance is thereby enhanced and the removal of large objects expedited with less likelihood of damage to the structure.

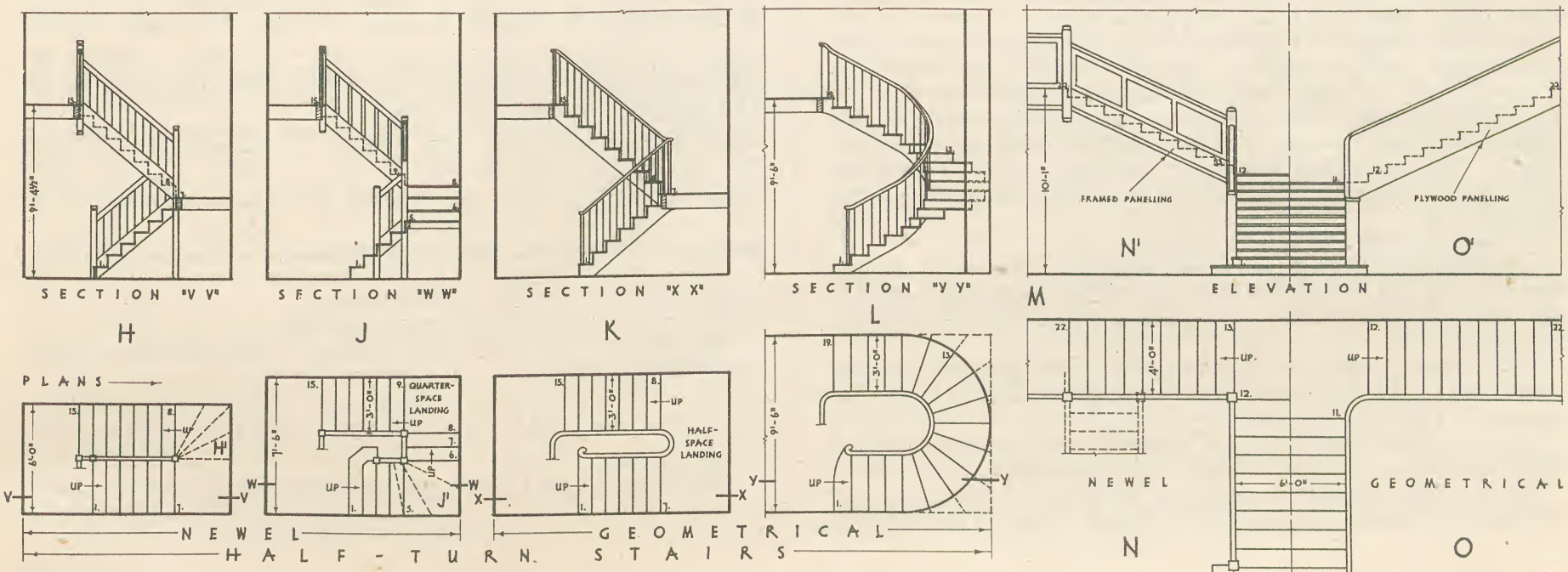
7. Adequate headroom must be provided. As already mentioned, the minimum headroom, measured vertically from the outer lower edge of an apron to the line of nosings, should be 6-ft. 6-in.; an alternative measurement is 6-ft. at right angles from the line of nosings to this edge of the apron.

This minimum height cannot always be obtained, and as a result large furniture can only be negotiated with difficulty; when this height is unduly restricted, injury may be caused to tall persons, especially when descending the stairs.

[1] This rule is sometimes departed from and the bottom three or four steps are made slightly wider than the rest, the increase being gradual with a maximum width at the first tread.

# TYPES OF STAIRCASES




NOTE: THE PROPORTIONS OF THE STEPS OF THESE STAIRS COMPLY WITH THE RULE "GOING PLUS TWICE RISE EQUALS 23" TO 24"". THUS, THE GOING & RISE OF THE STEPS ARE 11" & 6" AT "L", 12" & 5½" AT "M" AND 9" & 7½" AT THE REMAINDER.

SCALE FEET

FIGURE 29

8. Winders, unless they are of the type shown at G and L, Fig. 29, or are arranged as dancing steps (see J′, Fig. 29), may be a source of danger, especially to young children, and they should therefore be avoided. This is not always possible when the going is greatly restricted, and winders may then have to be utilized either at the top or, preferably, at the bottom of a flight; in cramped positions there may be no alternative to the provision of winders at both the head and foot of a flight.

When used, it is usual to divide what would otherwise be a quarter-space landing into three winders, as shown in Fig. 38. If four are used, as shown by broken lines at H′, Fig. 29, the average width of each tread is inadequate; if two only are provided, as shown at B′, Fig. 29, the average width of the treads is excessive, they are difficult to carpet, and the corner between the riser, lower tread and wall string is not easy to clean.

9. The height of a raking handrail (*i.e.*, parallel to the pitch) should be 2-ft. $7\frac{1}{2}$-in. measured vertically from the line of nosings to the top of the handrail (or 2-ft. measured normally from the line of nosings), and that of a horizontal handrail should be 3-ft. (see C, Figs. 30 and 32, and C and D, Fig. 36).

10. A stair should be in such a position that it can be conveniently approached from the lower rooms and afford a ready access to the upper rooms. Doors should be situated at least 1-ft. from the head and foot of a stair. A door which opens immediately off a top step is least desirable as it creates a potential danger, especially to visitors; and there is, of course, less risk of a collision occurring between a person hurriedly descending a stair and one leaving a room through a door which is not directly adjacent to a bottom step.

STEP PROPORTIONS.—A well-designed stair, even when the floor space is limited, should entail the minimum expenditure of energy in its ascent, and it must therefore be neither steep nor inadequately pitched (see 2, p. 80). The step of the average person measures approximately 23-in. and it has been computed that about twice the effort is required in climbing to walking horizontally. The following two rules, based apparently upon the foregoing, have been proved by experience to give a satisfactory ratio between the rise and going of a step:

1. Going plus twice rise equals 23 to 24-in.

2. With a 12-in. going and a $5\frac{1}{2}$-in. rise as a basic ratio, for every inch deducted from the going half an inch is added to the rise, *i.e.*, 12-in. going and $5\frac{1}{2}$-in. rise, 11-in. going and 6 in. rise, 10-in. going and $6\frac{1}{2}$-in. rise, 9-in. going and 7-in. rise, etc.

Rule 2 therefore agrees with rule 1 in so far as the going plus twice rise equals 23-in. in each case. Rule 1 has been complied with in all of the stairs illustrated in Figs. 29-39 inclusive.

Another common rule is: Going multiplied by tread equals 66-in. It will be seen that this does not agree with rule 2 when the going is less than 11-in.

Whilst a stair conforming to either rule will give satisfactory results, and it is therefore desirable to be guided by them when designing a stair, it will be realized that occasionally in practice a very restricted going of a flight is unavoidable and strict compliance is not then possible.

The nosing is, of course, additional to the going, and the projection of the tread beyond the face of the riser should preferably not exceed the thickness of the tread, as an excessive projection may cause a person to trip when ascending.

A stair with very narrow treads cannot be descended comfortably, as more than the usual care has to be taken to clear the nosing with the heel to obtain adequate foothold on the tread below. For this reason the preferred minimum going is 9-in. A satisfactory proportion for house stairs is a 10-in. going [1] and a $6\frac{1}{2}$ to 7-in. rise. In public buildings, where the stairs are a prominent feature and ample space is usually available, it is common to employ a 12-in. going and a $5\frac{1}{2}$ to 6-in. rise.

STAIR DESIGN.—The essential requirements specified on pp. 80 and 82 should be kept in mind when designing a stair. The type of stair decided upon depends a good deal upon the size and shape of the stairway.

The number of steps to be decided upon is governed to a large extent by the total going available. If the height from floor to floor is fixed, as it usually is, and the going is unrestricted, the number of steps is determined in the following manner: Assuming that the proposed rise is to be between $6\frac{1}{2}$ and 7-in., say $6\frac{3}{4}$-in. (which, as stated above, is satisfactory for a house stair), the number of risers equals the height divided by $6\frac{3}{4}$. Thus, if the floor to floor height is 9-ft. 3-in. (111-in.), the number of steps equals $\frac{111}{6\frac{3}{4}} = 16$ or 17. Adopting the latter figure, the exact rise is $\frac{111\text{-in.}}{17} = 6\frac{9}{17}$-in. The going will then $= 23\text{-in.} - (2 \times 6\frac{9}{17}\text{-in.}) = 23\text{-in.} - 13\frac{1}{17}\text{-in.} = 9\frac{16}{17}$-in., say 10-in. It should be noted that the number of treads is one less than that of the risers, as the surface of the upper floor forms the tread for the top step.

If the going of the flight is so restricted that the minimum going of 9-in. (see above) can only be adopted, then the number of steps equals $111\text{-in.} \div \frac{23\text{-in.} - 9\text{-in.}}{2} = 15$ or 16. Adopting 15 as the number, the rise of each step $= \frac{111\text{-in.}}{15} = 7\frac{6}{15}$-in. This will be satisfactory, as it conforms to rule 1, *i.e.*, $9\text{-in.} + (2 \times 7\frac{6}{15}\text{-in.}) = 9\text{-in.} + 14\frac{4}{5}\text{-in.} = 23\frac{4}{5}$-in.

This matter is again referred to on pp. 83 and 93.

The construction of straight flight, dog-leg and open well stairs will now be considered in detail.

## STRAIGHT FLIGHT STAIR

This is detailed in Fig. 30.

The ground floor and first floor plans of a small house are shown at A and B.

[1] See footnote "1" on p. 83.

Owing to the restricted width available, the straight flight stair shown is the only type which can be adopted; an excess in the preferred maximum number of steps in a flight (see requirement 5, p. 80) is unavoidable. Useful storage accommodation is afforded when, as shown, the space under the stairs is utilized as a cupboard. The foot and head of the stair are approximately 1-ft. from the living-room and bedroom No. 1 doors respectively (see requirement 10, p. 82).

Enlarged plan, longitudinal and cross-sectional elevations of the stair are shown at D, C and E.

CONSTRUCTION OF STEPS.—Owing to the limited going of the flight, the minimum width of tread (9-in. going [1], see p. 82) has been adopted, and it will be seen that only fourteen steps can be provided if requirement 10 is complied with. As the height from floor to floor is 8-ft. 9-in. (see C), the rise of step equals $\frac{\text{8-ft. 9-in.}}{14} = 7\frac{1}{2}$-in. This proportion of step agrees with rule 1, *i.e.*, 9-in. $+ (2 \times 7\frac{1}{2}\text{-in.}) = 24$-in.

The nominal thickness of the treads should not be less than $1\frac{1}{4}$-in.[2] and that of the risers is usually 1-in. The enlarged detail at F shows one good method of connecting the treads to the risers, both edges of the latter being tongued into the grooved treads and screwed (preferably) as shown, or nailed. The nosing, as previously explained (p. 82), should not project more than the thickness of the tread. This simple nosing—the square edges are just sand-papered—is all that is necessary for this type of stair; if the stair, having nosings as shown, is not to be carpeted, it is advisable for the treads to be of hardwood (such as teak or oak) and not softwood, as the edges are apt to be damaged; incidentally, as felt pads are usually used to protect a carpet, such relatively sharp upper edges do not damage a carpet. Another good method of jointing treads and risers is shown at E, Fig. 35, where the treads are tongued at their inner edges into the risers; this also shows an alternative simple nosing. Another nosing is shown at D, Fig. 31, a scotia or cavetto mould being used; as this moulding is fitted into the grooved tread, there is no need for the riser to be tongued; alternatively, the top outer edge of the riser is tongued to fit the grooved tread, and the moulding is just glued and sprigged to the tread. A common nosing is the half-round, such as is indicated in Fig. 39. A cheap and second-rate method of jointing is shown at P, Fig. 30; here the members are just butt-jointed and nailed together, hence any shrinkage of the risers and especially the treads, results in unsightly gaps occurring through which dust passes.

The treads and risers are supported by two 14-in. by $1\frac{1}{2}$-in. wall strings which are securely plugged to the walls (see C, D, E and detail at G). A 2 to 3-in. wide margin is provided and, as shown at G, the upper edge of the string is rounded and rebated to provide a simple but effective finish between it and the plaster. As the width of the stair is 3-ft., it is desirable to use an intermediate support in the form of a 4-in. by 3-in. (or 2-in.) bearer or carriage-piece; this is birdsmouth notched and nailed to a short fillet at the foot (or it may be continued through the floor and notched to a deep conveniently placed floor joist) and similarly secured to the wall plate at the head. In order that the carriage-piece may afford the maximum support, 1-in. thick short pieces of wood (often pieces of floor board), called *rough brackets*, and shaped as shown at C, are nailed to the sides with their upper edges cut square and brought tightly up to the underside of the treads to which they are nailed; these brackets are fixed alternately to the bearer as shown (see also C, Fig. 31). As an alternative to these brackets, triangular blocks are nailed on the upper edge of the carriage as shown at A and G, Fig. 38. In the illustrated examples, the inner edges of the treads or risers (depending upon the type of joint) are shown resting upon the carriages, but sometimes the latter are slightly notched to receive the steps.

In addition to strengthening a stair, these carriage-pieces serve as an intermediate fixing for the laths when, as in this case, the soffit is to be plastered (see C and E). It is a common practice, especially in inferior work, to omit these intermediate bearers, even when the width of the stair is 3-ft., and as a result the stairs creak owing to the deflection, and defects in the plaster arise.[3]

The wall strings are shown to be 14-in. by $1\frac{1}{2}$-in. (see C). This width is necessary if the soffit is plastered and the laths are to be nailed to the lower edges of the string (see E). An alternative form of construction is shown at A, B and C, Fig. 31, where narrower strings (11-in. or 10-in. by $1\frac{1}{2}$-in.) are employed, together with two additional 4-in. by 2-in. bearers. These narrow strings, without the two additional bearers are adequate if the soffit is not plastered.

The ends of the treads and risers are housed into the wall strings, the amount of housing varying from $\frac{3}{8}$ to $\frac{5}{8}$-in.—usually $\frac{1}{2}$-in. (see G, Fig. 30). The grooves, trenches or housings to receive these ends are tapered and are of sufficient width to permit of the insertion of tapered wedges, preferably of hardwood. These wedges (see L, Fig. 31), after being dipped in glue, are driven in from the back. The tread wedges thus bring the treads tightly against the upper cuts of the housings, and the riser wedges cause the faces of the risers to fit tight against the outer vertical housing (see G, Fig. 30, C, D and H, Fig. 31, F, Fig. 32, etc.).

Additional rigidity is obtained by the provision of small triangular blocks, termed *glue blocks*, which are glued in at the inner angles formed between the treads and risers. These are spaced at 3 or 4-in. apart (see C, F and G, Fig. 30, and A, B, C and D, Fig. 31, etc.). They are also glued to the strings and treads, and occasionally at the angles between the risers and the strings.

The construction of the upper floor at the landing is shown at C, D and E. the ends of the joists being supported on a wall plate. The $1\frac{1}{4}$-in. thick nosing

[1] This 9-in. going has also been adopted in most of the illustrated examples on account of the restricted size of drawing sheet.

[2] Wood treads of stairs for offices, etc., subjected to heavy traffic are sometimes $1\frac{1}{2}$ to 2-in. thick,

[3] If no intermediate bearer is provided and the soffit is to be plastered, the laths are not fixed transversely but are parallel to the pitch and are nailed direct to the inner edges of the steps, as shown by broken lines in Fig. 33.

forming the top step is either tongued and grooved or splay jointed to the adjacent floor board(s); see G, Fig. 32.

HANDRAIL.—A handrail should be of suitable size and shape in order that it may be readily grasped by the hand, and it should be fixed at a convenient height; sharp arrises on a moulded handrail must be avoided to prevent injury to a person's hand, especially during a rapid descent of a stair. Two forms of handrail are shown at C and these are detailed at H and J. The former is a very common wall handrail and is securely plugged to the wall; it is usually of pitch pine or a hardwood. That shown at J is of hardwood, circular in section, and is screwed to a continuous stainless steel bar which is set-screwed to metal brackets, secured at approximately 4-ft. intervals to plugs. As this latter handrail projects at least 3-in. from the plaster, it is not a suitable form for narrow stairs (see p. 93). As shown at C, the height from the line of nosings to the top of the handrail is 2-ft. $7\frac{1}{2}$-in.

HEADROOM.—Adequate headroom is most important, and it is an essential which is occasionally overlooked. As stated on p. 80, it should be at least 6-ft. 6-in. In this example the upper floor is continued over the "lobby" (see A) and the space thus available is utilized to provide a cupboard or fixed wardrobe to each of the bedrooms Nos. 1 and 2 (see B). Such provision does not encroach upon the headroom, which is 6-ft. 9-in. (see C). As shown, the partition across the stair is a stoothing consisting of 4-in. by 2-in. vertical studs, secured to the floor and ceiling joists, and lathed and plastered both sides (see p. 42); the partition between the cupboards is a similar stoothing, but the studs need only be 3-in. by 2-in. at 15-in. centres.

CUPBOARD UNDER STAIR.—It is usual to utilize the space under the stair by providing useful storage accommodation as shown at A, C and D. The door, of course, opens outwards. The lintel above it is shown supporting brickwork; alternatively, four 4-in. by 2-in. short vertical studs may be used, nailed to the lintel and wall plate. A low stoothed partition consisting of three 3-in. by 2-in. studs is fixed to block out a corner which would be otherwise difficult to keep clean and a portion of the floor which would serve no useful purpose. Floor boards between this partition and the bottom of the stair may be omitted to provide ventilation to the stair timber. A suitable finish is afforded by plastering the interior or by fixing wall boards (see pp. 48 and 49) to the walls, partition and soffit.

*Setting Out on Paper.*—In setting out the stair on paper the student should first draw the plan, the nosings (or faces of risers) being spaced by the accurate application of the scale. The longitudinal section is then developed from the plan. The height shown in this section can be expeditiously divided into the requisite number of steps in the following manner: Draw a line representing the landing level at 8-ft. 9-in. above the ground floor. Using any convenient scale, place it at an angle on the paper with the zero division intersecting the landing (or ground floor) and the fourteenth division coinciding with the ground floor level (or landing, depending upon the end from which the scale reads), and carefully tick off the intermediate divisions 1 to 13 inclusive. Horizontal lines drawn through these points give the treads, and when connected with the vertical lines developed from the divisions on the plan the required fourteen steps are set out. It is advisable to number each step on plan as shown and also on the section during its development. The direction "up" should be indicated on the plan at the foot of the stairs; this removes ambiguity and facilitates the reading of a drawing, especially when a stair consists of several flights. The rest of the details can be completed without much difficulty, an adjustable set square being useful for drawing the string, line of nosings (to check for accuracy) and handrail. The importance of ensuring adequate headroom is again emphasized.

*Setting Out and Construction in Workshop.*—The fixing and trimming (if any) of the floor joists will have been completed and the floor boards laid before the construction of the stairs is commenced. As there is usually some discrepancy between the dimensions taken from a plan and those of the building, it is necessary to obtain the exact total rise and going of a stair from the actual building. A storey rod (see p. 80) is used for this purpose. To obtain the correct height from floor to floor, the rod, resting on the ground floor, is held vertically (a plumb-bob being used to ensure this) against the end of one of the wall landing joists. The height of the upper floor boards is carefully marked on the rod and the word "rise" is written below it; the point where the suspended bob touches the floor is marked. This height is checked by taking a measurement near to the opposite wall.

The position of the face of the bottom riser is marked on the ground floor (or wall) and the horizontal distance between this and the "bob" point previously marked is measured and marked on another face of the storey rod, and the word "going" is written on it. On being taken to the shop, the "rise" face of the rod is divided by compasses into fourteen equal parts, being the number of risers required. The distance that the face of the top riser is to be from the edge of the landing is marked from one end of the "going" face of the rod, and the net going is then divided into thirteen equal parts. The subsequent operations depend upon whether the strings are to be trenched or housed by (*a*) hand or by (*b*) machine.

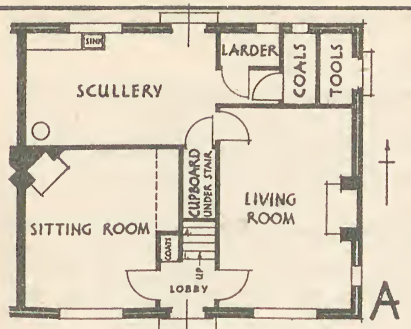
(a) *Hand Trenching.*—A pitch-board, a tread templet and a riser templet are required for setting out a string for the trenchings or housings. One form of pitch-board is shown at E, Fig. 31. It consists of a thin wood set square having a rise and going equal to the dimensions taken from the storey rod; this is tongued into a thicker board of width equal to the required margin and this is housed to a wood base at right angles. A tread templet is shown at F, it is shaped to the required nosing and of a tapered width equal to the thickness of a tread and wedge. Similarly, the riser templet G is equal in width to the combined thickness of a riser and wedge. The length of the strings should be slightly in excess of the *pitch edge* (see E) multiplied by the number of steps, together with the portions required to meet the top and bottom skirtings; the ends of the strings are afterwards trimmed off to accurate length on the job and the skirtings fitted to them.

A brief description of the setting out is given at H, Fig. 31. After the string has been dressed the nosing line is pencil marked at the required distance from the upper edge. The compasses are set to the length of the pitch edge and fourteen divisions are pricked off along this line. Commencing at one end, and with the base of the pitch-board pressed against this edge of the string, the outside of the first riser and going is *knife* marked along the "rise" and "going" edges. Still maintaining the board in this position, the riser templet is placed against it with the corner of end *b* coinciding with *b'* marked on the board, and the back or wedge-line is marked; the tread templet is then placed as shown against the board with its mark *a* at the *a'* point of the pitch-board, and the nosing and underside or tread wedge-line marked. The pitch-board is then slid along the string and the housing for the next step is marked off in a similar manner.

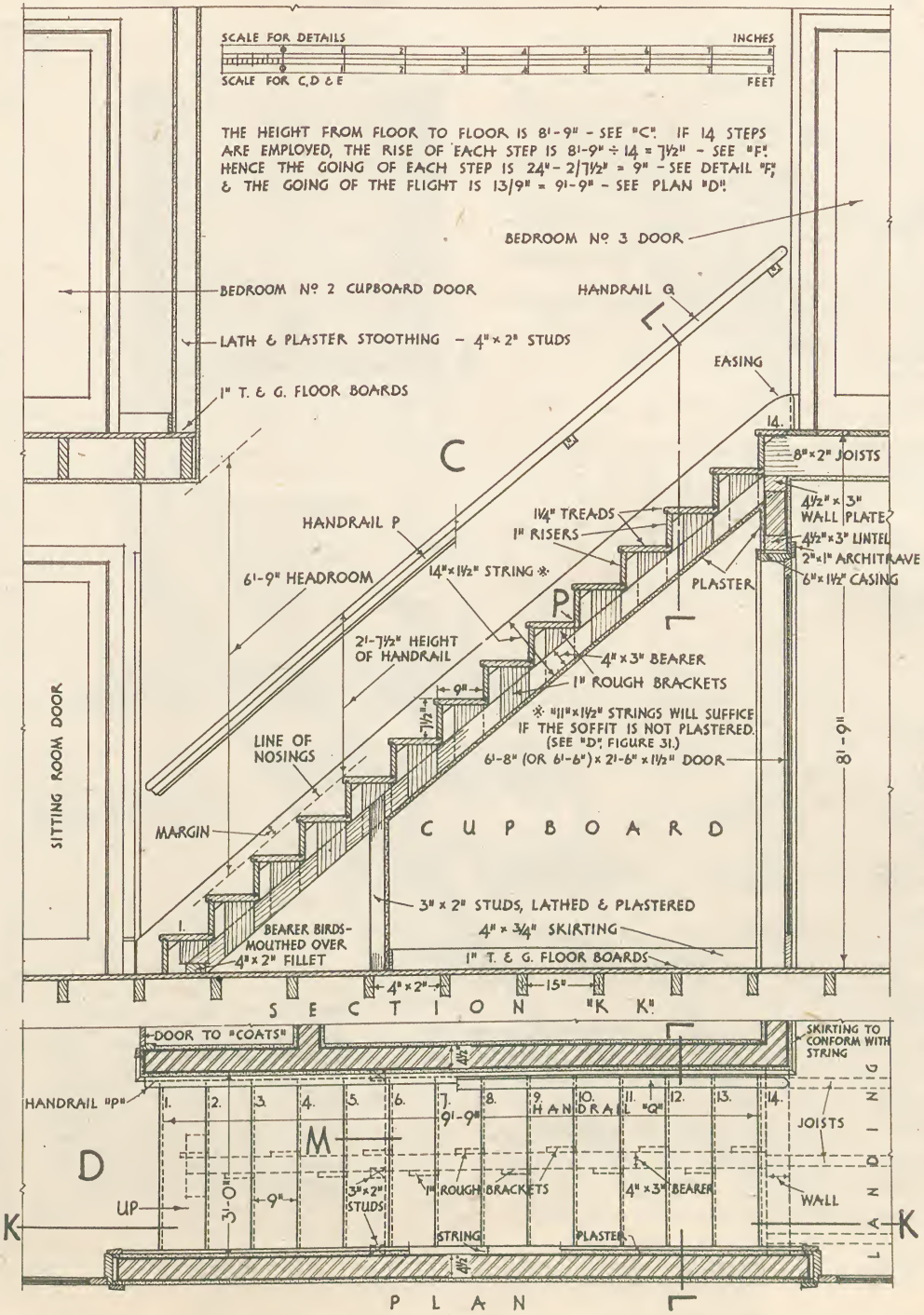
Three or four holes are sunk with a brace and bit near the nosing of each step and tangential to the outer faces, and the wood between is chiselled out; this permits of the use of the tenon saw for forming cuts along the marked lines, after which the remaining core is removed by a chisel and the bottom of the trenchings finally levelled with a router plane to give a $\frac{1}{2}$-in. sinking (see G, Fig. 30). The second string is then set out and the housings formed as described.

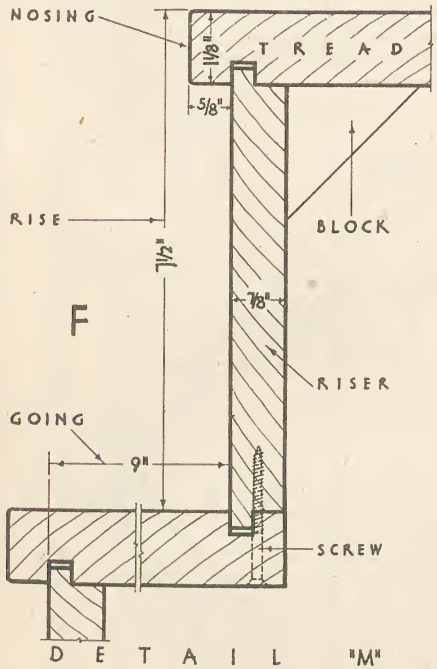
(b) *Machine Trenching.*—Simple appliances are now available for the rapid setting out and complete trenching of straight strings. Machines, called *stair trenchers*, are

# STRAIGHT FLIGHT STAIR

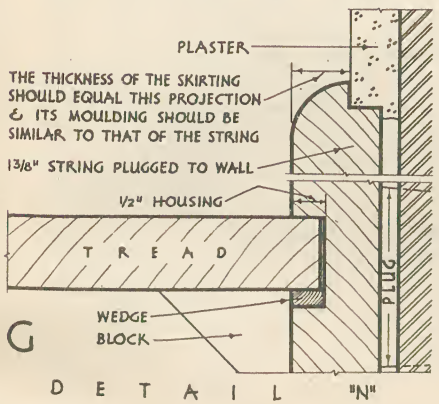



KEY GROUND FLOOR PLAN OF SEMI-DETACHED HOUSE

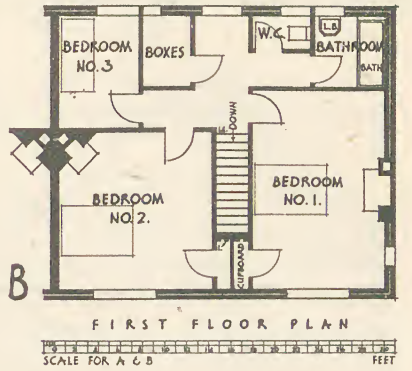

SCALE FOR DETAILS
INCHES
SCALE FOR C,D & E
FEET
THE HEIGHT FROM FLOOR TO FLOOR IS 8'-9" - SEE "C". IF 14 STEPS ARE EMPLOYED, THE RISE OF EACH STEP IS 8'-9" ÷ 14 = 7½" - SEE "F". HENCE THE GOING OF EACH STEP IS 24" - 2/7½" = 9" - SEE DETAIL "F" & THE GOING OF THE FLIGHT IS 13/9" = 9'-9" - SEE PLAN "D".
BEDROOM Nº 3 DOOR
BEDROOM Nº 2 CUPBOARD DOOR
HANDRAIL Q
LATH & PLASTER STOOTHING - 4" × 2" STUDS
EASING
1" T. & G. FLOOR BOARDS
8"×2" JOISTS
4½" × 3" WALL PLATE
4½"×3" LINTEL
2"×1" ARCHITRAVE
6"×1½" CASING
PLASTER
1¼" TREADS
1" RISERS
HANDRAIL P
6'-9" HEADROOM
14"×1½" STRING ※
2'-7½" HEIGHT OF HANDRAIL
4" × 3" BEARER
1" ROUGH BRACKETS
※ "11"×1½" STRINGS WILL SUFFICE IF THE SOFFIT IS NOT PLASTERED. (SEE "D", FIGURE 31.)
6'-8" (OR 6'-6") × 2'-6" × 1½" DOOR
SITTING ROOM DOOR
LINE OF NOSINGS
MARGIN
CUPBOARD
81-9"
3" × 2" STUDS, LATHED & PLASTERED
4" × ¾" SKIRTING
1" T. & G. FLOOR BOARDS
BEARER BIRDS-MOUTHED OVER 4"×2" FILLET
4"×2"
15"
SECTION "K K"
DOOR TO "COATS"
SKIRTING TO CONFORM WITH STRING
HANDRAIL "P"
HANDRAIL "Q"
JOISTS
WALL
STRING
PLASTER
91-9"
3'-0"
9"
3"×2" STUDS
1" ROUGH BRACKETS
4" × 3" BEARER
UP
LANDING
PLAN




DETAIL "M"

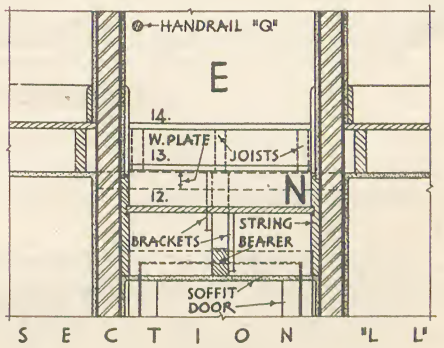



DETAIL "N"



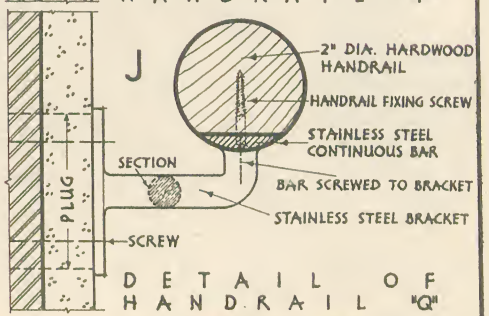

FIRST FLOOR PLAN

SCALE FOR A & B FEET




SECTION "L L"

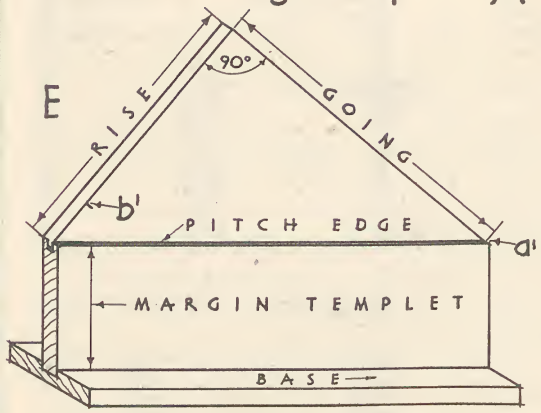
DETAIL OF HANDRAIL "P"



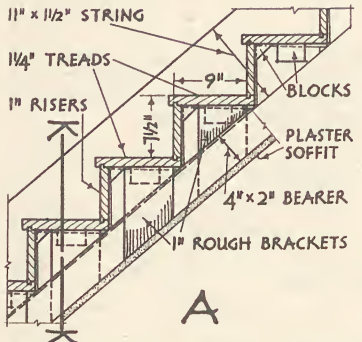

DETAIL OF HANDRAIL "Q" AS ALTERNATIVE TO HANDRAIL AT "H"

FIGURE 30

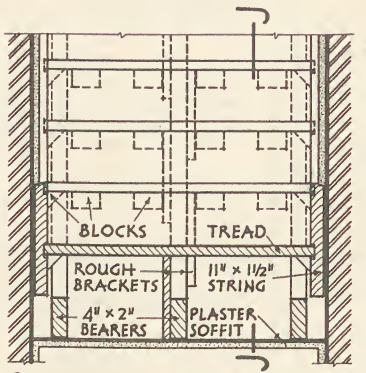
# STAIR DETAILS



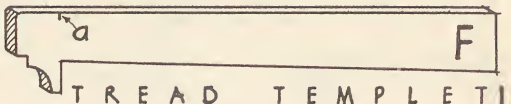

PITCH-BOARD



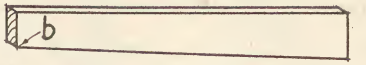

SECTION "J J"




SECTION "K K"

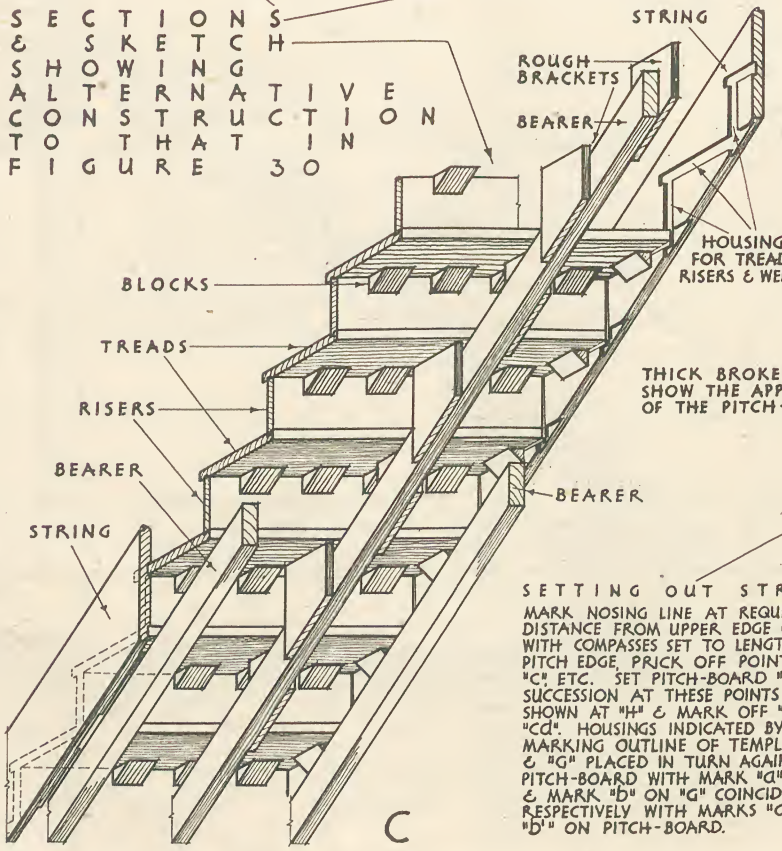


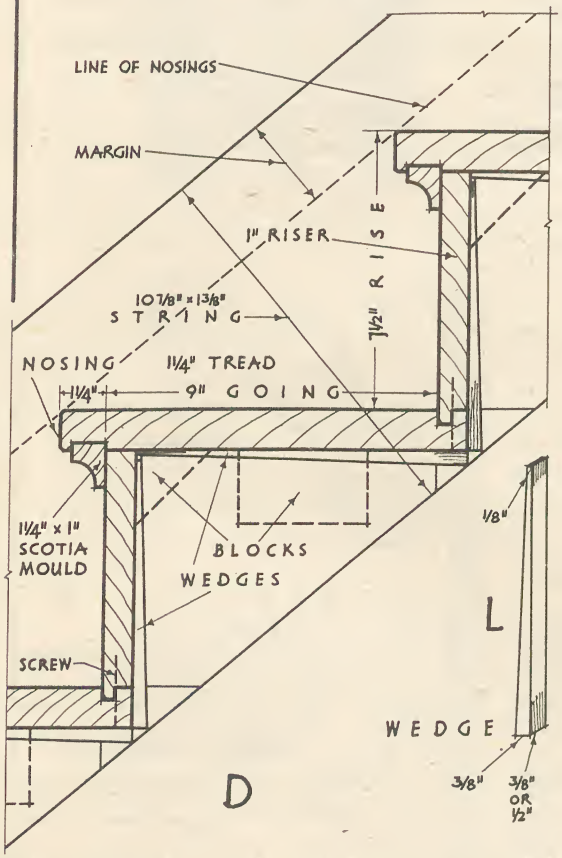

TREAD TEMPLET




RISER TEMPLET

SECTIONS & SKETCH SHOWING ALTERNATIVE CONSTRUCTION TO THAT IN FIGURE 30







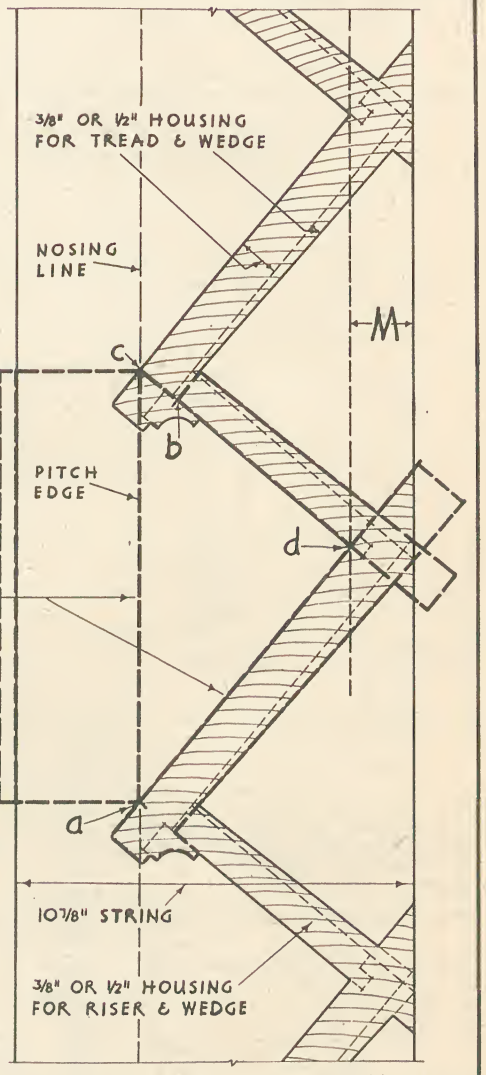
ALTERNATIVE DETAIL TO "A" SHOWING MOULD AT NOSING

FIGURE 31

THICK BROKEN LINES SHOW THE APPLICATION OF THE PITCH-BOARD

SETTING OUT STRING

MARK NOSING LINE AT REQUIRED DISTANCE FROM UPPER EDGE OF STRING. WITH COMPASSES SET TO LENGTH OF PITCH EDGE, PRICK OFF POINTS "a", "c", ETC. SET PITCH-BOARD "E" IN SUCCESSION AT THESE POINTS AS SHOWN AT "H" & MARK OFF "ad" & "cd". HOUSINGS INDICATED BY PENCIL-MARKING OUTLINE OF TEMPLETS "F" & "G" PLACED IN TURN AGAINST THE PITCH-BOARD WITH MARK "a" ON "F" & MARK "b" ON "G" COINCIDING RESPECTIVELY WITH MARKS "a'" & "b'" ON PITCH-BOARD.




PLAN OF STRING GIVING METHOD OF SETTING OUT FOR TREADS AND RISERS

SCALE FOR D,E,F,G,H & J — INCHES

SCALE FOR A,B & C — FEET

also obtainable, the latest type of which will cut the trenches of *two* strings in less time than it normally takes a man to *set out* one.

A simple device consists of a metal grooved templet which is graduated to permit of its adjustment to the required rise and going. The only setting out line required is that shown at M (see H, Fig. 31) which is pencil marked at the required distance from the lower or back edge of the string. The templet is clamped to the string in the desired position, and the trenches for the first riser and tread are routed out by means of a cutter which is easily manipulated between the slotted or grooved guides. A pencil mark is then made at the intersection between the gauge line M and the top of the tread cut, the templet is slid along until the outside of the riser guide intersects this mark, the appliance is again clamped and the trenches for the riser and tread of the second step are routed. This is repeated until the trenching of the string is completed.

A similar device can be attached to a spindle moulder (see B, Fig. 5 and p. 29) and the trenching of a string can be automatically completed at one setting.

The stair trencher referred to above consists, briefly, of a vertical cutter spindle, the cutter of which travels within guides (adjusted to the required going and rise) as it forms the trenches in both strings during a continuous operation.

There are several methods employed in assembling the various parts of a stair, depending upon local practice, if mass-produced, etc. In one method all of the treads are first fixed to the strings, followed by the risers. In another each step, with its tread and riser, is framed together ; the steps are then fitted in the trenches of one string, after which the second string is fitted and cramped.

Briefly, the sequence of operations in the first method are : After the strings have been trenched and the treads and risers have been prepared (*i.e.*, tongued, grooved, nosed, cut square to correct length and dressed), the first and last treads are housed into the corresponding trenches of both strings, cramped after being tested for squareness, nailed and wedged. The strings are now placed with their front or upper edges resting on the bench, and the remaining treads are inserted between the trenches, each being tested, cramped and glue wedged in turn. After the outer ends of the wedges have been removed as required, the risers are inserted and wedged. The treads and risers are then screwed (in best work—see F, Fig. 30) or nailed and glue blocks are fitted to the inner angles. The treads may also be skew screwed or nailed to the string. Scotia mouldings, if required, are glued and sprigged to the treads.

In the second method the steps are made separately before being fixed to the strings. One simple appliance, called a *cradle*, which is employed to ensure that the riser is fitted at right angles to the tread, consists of two angle brackets, each being a 3-in. by 2-in. by 18-in. long wood bearer to which a shorter piece of similar scantling is securely fixed vertically and squarely at one end ; each upright or leg is notched on its inner edge where it joins the horizontal bearer, the size and shape of the notch being similar to the nosing of the tread (and scotia, if needed) ; the brackets are screwed to the top of the bench, at about 2-ft. apart, the horizontal members being parallel to each other and at right angles to the base of a try square used for ensuing squareness. The tread, outer face downwards, is placed on the bearers with the nosing engaged in the notches of the uprights. The upper tongued edge of the riser is glued and fitted into the groove of the tread as the riser is held against the uprights. The blocks are then glued and fitted to the inner angle. If required, the scotia is glued and inserted before the riser is fitted. When the glue is sufficiently dry, the step is carefully removed and allowed to set. After all the steps have been formed in this manner, the next operation is to fix them to the strings. A string, with its trenched face uppermost, is placed on the bench and each step is placed vertically with its lower end fitted into the trench. When all the steps have been housed, the second string is placed in position with the upper ends of the steps engaging in the trenches. The stair is then cramped ; if the flight is assembled on a bench specially equipped for this purpose, the cramps employed will be of the overhead type ; otherwise ordinary T-cramps are used. The treads and risers are now wedged, care being taken to see that each tread is driven tightly against the trench nosing before the tread wedge, well glued, is driven home. To ensure that none of the nosings are out of winding, a straight edge is applied to them and any nosing not touching it is driven tighter as required. Glue blocks are fitted between the treads and strings, and treads are screwed to risers, etc., as described above. The top nosing is neatly tongued and grooved or splay jointed to the adjacent floor boards after the stair has been fixed.

As previously mentioned, the stair is well secured by nailing the strings to plugs which have been driven into the joints of the brickwork. The 4-in. by 3-in. bearer or carriage (see C, Fig. 30) is then birdsmouthed and securely nailed to the fillet at the foot and the wall plate at the head. The 1-in. rough brackets are sawn to shape and each is well spiked to the side of the bearer after its upper edge has been glued and fitted to the underside of the tread.

The ends of the strings are cut to the required length—any easings having been previously formed—and the skirtings are neatly fitted to them. Attention is drawn to the note at G, Fig. 30, to the effect that the moulding on the skirting should conform to that on the string, and its thickness should be equal to the projection of the string beyond the face of the plaster. A clumsy finish frequently results because of inattention to this detail.

Fixing of the handrail to the wall, at the required height, completes the stair.

## DOG-LEG STAIR

This is so called because of its appearance in sectional elevation. It is a convenient form when the going is restricted and sufficient space equal to the combined width of two flights only is available. It is illustrated at B and H, Fig. 29, and in Figs. 32, 33, 34 and 35.

Small scale plans of a house showing the application of this type of stair are given at A and B, Fig. 32, and a larger scale plan and sections are shown at C, D and E. Reference to the isometric sketch of this stair at A, Fig. 34, will give a better idea of its appearance. It will be seen that the balustrade of the upper flight is immediately over that of the lower.

STEPS.—A detail of the steps and a note upon their proportions are given at F, Fig. 32. The inclined risers are an alternative to the more usual vertical form already described and give an attractive appearance to the stair, especially if a simple nosing is employed. The edge of the nosing is parallel to the riser, the slope of which should not be too flat, otherwise the projection of the nosing beyond the bottom of the face of the riser will be excessive (see p. 82). The jointing, housing, wedging, blocking and bracketing of the steps are as described for the straight flight stair. The bottom splayed step is detailed at D and E, Fig. 39.

STRINGS AND NEWELS.—The outer ends of the steps are housed into the outer strings, the thickness of which is usually $\frac{1}{2}$ in. more than that of the wall strings, *i.e.*, 2-in. As the stair is 3-ft. wide and the upper flight at least has a plastered soffit, the upper string is necessarily wide (see L, Fig. 34), but the lower outer string need only be 10-in. (nominal) wide (see F, Fig. 32), as the spandrel is panelled (see C). This outer string of the upper flight may be in one piece, 15-in. wide (see M, Fig. 34), or it may consist of two tongued and grooved pieces (see B and L, Fig. 34) ; for narrower stairs, when a rough carriage is not required, the laths of the plastered soffit may be nailed direct to the steps and parallel to the pitch (shown by broken lines in the detail in Fig. 33). Both outer strings are secured to 4-in. by 4-in. newels placed at the foot and head of

each flight. The strength of the stair depends a good deal upon the rigidity of these newels and the method of jointing the strings to them. The bottom newel is continued through the floor and well nailed or bolted to a 3-in. thick joist (see also C, Fig. 36). The central newel is continued to the floor (see C, Fig. 32) to which it is nailed ; whilst this is a common practice, greater rigidity is obtained if it is continued through the floor and secured to a convenient joist ; this newel is also notched to the trimmer joist to which it is securely nailed or bolted (see also Fig. 33). The upper newel is also notched to the 9-in. by 3-in. trimmer (see C and G, Fig. 32).

Details of the draw-pinned joints between the newel and the strings at B, Fig. 34, are given in Fig. 33. These show at the end of each string two oblique haunch tenons which are fitted into mortises formed in the newel and secured by a pin or hardwood dowel at each tenon. The tenons are formed in the centre of the strings (see sketch in Fig. 33), and if the tenon holes for the dowels are bored slightly nearer to the shoulders than the distance the newel holes is from the edge of the newel, a tight fit between the shoulders and the newel will be assured when the slightly tapered glued dowels are driven in. An alternative but inferior joint, adopted in cheap work, is to form barefaced tenons on the outside of the strings with shoulders on the inside.

Note that the nosings of the treads are set slightly back from the edges of the newels.

LANDINGS.—The half-space landing is constructed of 4-in. by 2-in. joists, supported by the wall at one end and dovetail housed at the other to a 7-in. by 3-in. trimmer which spans the opening and is carried by the walls (see C and D, Fig. 32, Fig. 33 and A, Fig. 34) ; the narrow top tread of the lower flight is rebated over the trimmer and is tongued and grooved to the floor board. The construction at the top landing is similar (see C, D, E and G, Fig. 32), but one end of the 9-in. by 3-in. trimmer joist is tusk tenoned into a 9-in. by 4-in. joist (see Q at B) supported on the wall between the dining-room and hall and that dividing the vestibule and stair ; this latter joist also supports the 4-in. by 2-in. vertical studs forming the small box-room partition (see also A, Fig. 34 and p. 42). The 4-in. by 2-in. bearer or rough carriage of the lower flight is well nailed at the foot to the floor and joist below, and its upper end is birdsmouthed and nailed to a 4-in. by 3-in. *pitching piece* or trimmer which is tenoned to the newel at one end and supported by the wall at the other (see C). The upper carriage is well secured to the trimmers.

HANDRAIL.—The handrail for the upper flight is housed, tenoned and dowelled (draw-pinned) to the two newels (see C, Fig. 32 and Fig. 33). The interception of the upper end of the lower handrail by the upper outer string is unavoidable. Besides the unsatisfactory appearance thus presented, the absence of a handrail at the top of this flight is inconvenient, if not dangerous, and therefore an additional handrail (similar to that shown at H, Fig. 30) is sometimes fixed to the wall at the lower flight. The handrail of the balustrade provided at the top of the landing is 3-ft. high (see p. 82) and is fixed between a 4-in. by 4-in. newel and a 4-in. by 2-in. newel (known as a *half-newel*) plugged to the wall (see C and E, Fig. 32).

Alternative details of the balustrade are shown in Fig. 34. Sections through handrails are indicated at E and F. The strings at L and M have already been referred to ; the cover fillet at the lower edge of the string at L provides a suitable finish to the plaster, the groove being sufficiently deep to cover the ends of the laths which are nailed to the string ; this has a better appearance than the cheaper alternative at M, where the string is grooved to receive the laths and plaster. An alternative finish, suitable when the laths are fixed direct to the steps, is shown in section in Fig. 33. The appearance is also improved if a capping is fixed to the upper edge of each string ; two simple cappings are shown at J and K, Fig. 34 ; the strings shown in Fig. 33 are without cappings.

It will be noted that in all these details no unsightly gaps will be caused if the timber shrinks.

Two plain, but effective, solid moulded caps to the newels are shown at C and D, Fig. 34, and a drop, similar to C, is shown at N.

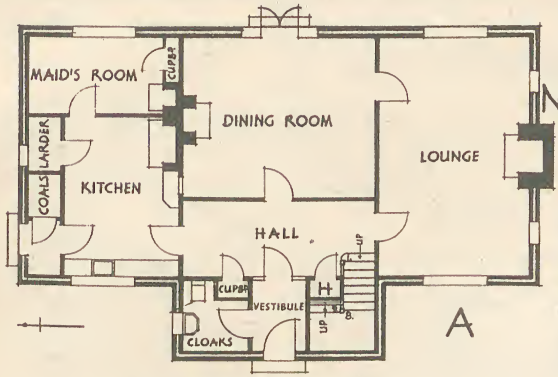
BALUSTERS.—The 2-in. by 1½-in. balusters shown in Fig. 32 are detailed at G and H, Fig. 34. They are usually spaced at 3 to 4-in. apart and arranged so that one is central at the intersection between the lower handrail and the upper string. If square balusters are used, they should be out of not less than 1¼-in. stuff (see A and B, Fig. 38), as 1-in. square balusters look spindly when dressed. Balusters may be either housed (as at E, Fig. 34) or tenoned (as at F) into handrails, and housed (see J) or tenoned (see K) into the cappings or strings (see also Fig. 33). A continuous groove is sometimes formed in the underside of the handrail and the upper ends of the balusters are slid into it. Alternatively, especially when the balustrade is to be painted, a continuous groove is formed in the upper edge of the string ; after the balusters have been fixed, the portions of the groove between them are filled in. For inferior work, and owing to the difficulty of housing or tenoning the balusters, they are cut to the pitch of the handrails and strings and simply nailed to them.

Additional balustrade details are illustrated in Figs. 35, 36, 37, 38 and 39.

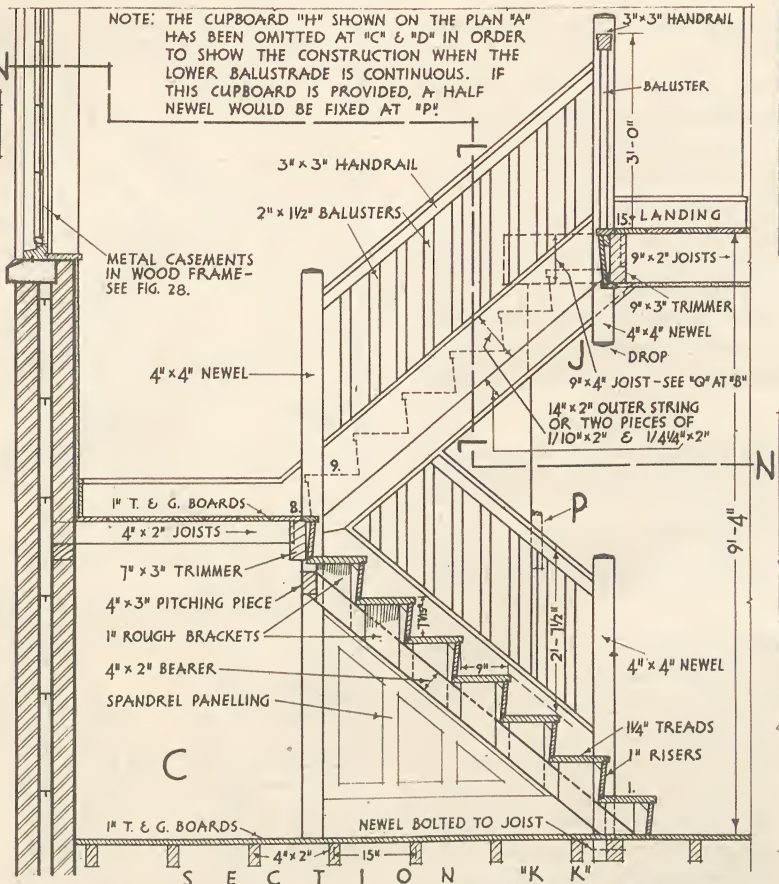
Bronze or similar metal balustrades are sometimes employed for wood stairs. Some details of this type are shown at K, L and M, Fig. 45, Vol. II, and could be applied here if modified to show the bottom of each baluster secured to a continuous bar (or provided with a flange) and screwed to the string, etc.

A detail showing a suitable finish to the upper floor, where the balustrade is returned to the wall, is shown at G, Fig. 32. The trimmer is covered with an apron lining, which is sloped to conform to the risers, and tongued and grooved to the nosing and cover fillet ; the lining may be of 3-ply. As the nosing is only slightly set back from the edge of the newel, it is advisable to provide small packing pieces as shown ; a solid bearing for the balustrade is thus afforded. The nosing is rebated over the trimmer and either tongued and grooved or splay-jointed to the floor board. Note that there is a slight margin between the

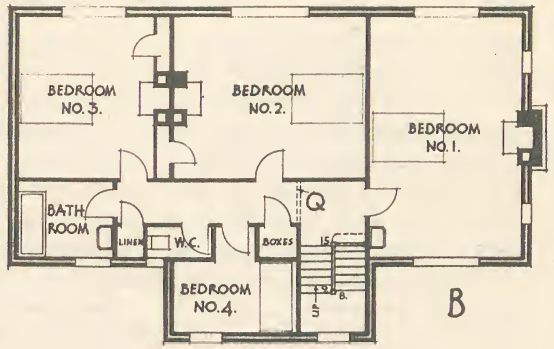
# DOG-LEG STAIR




KEY GROUND FLOOR PLAN OF DETACHED HOUSE

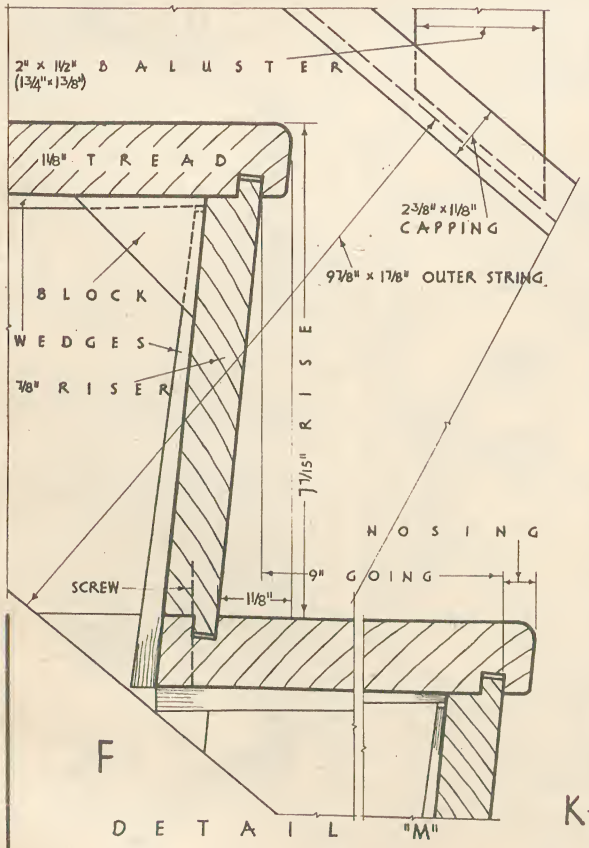



SECTION "K K"

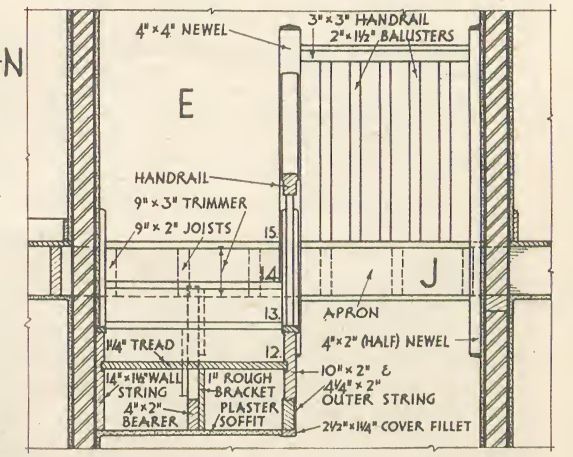



FIRST FLOOR PLAN

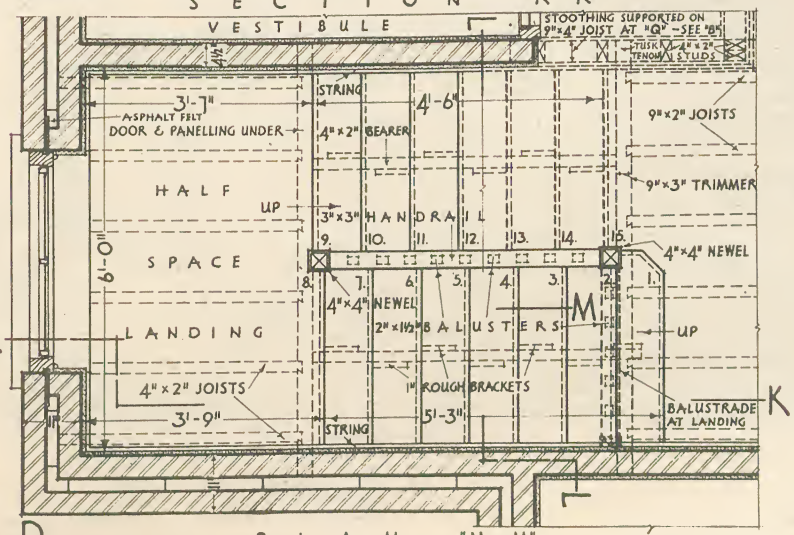
SCALE FOR A & B — FEET



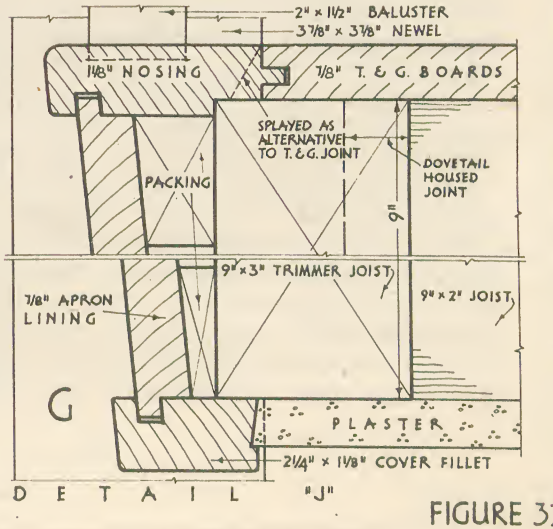

DETAIL "M"




SECTION "L L"




PLAN "N N"




DETAIL "J"

THE HEIGHT FROM FLOOR TO FLOOR IS 9'-4" - SEE "C". USING 15 STEPS, THE RISE OF EACH IS 9'-4" ÷ 15 = 7 1/15" - SEE "F". AS SHOWN AT "F" THE GOING IS 9" & THIS CONFORMS TO THE RULE "TWICE RISE PLUS GOING EQUALS 23" TO 24".

SCALE FOR F & G — INCHES

SCALE FOR C, D & E — FEET

FIGURE 32

edge (adjacent to the plaster) of the cover fillet and the edge of the newel. Alternative apron details are shown at M and N, Fig. 36.

The spandrel and the area between the long newel, wall, floor and the plastered soffit of the upper flight are shown panelled (see C and D, Fig. 32). Alternatively, these two areas may be filled in with coke breeze blocks (see F, Fig. 36) and plastered, or they may be stoothed (vertical studs and plaster). If an access door is provided (see note at D), the space under the stair can be used to accommodate gas and electric meters, fuse and switchboards, boxes, etc.

The isometric sketch of this staircase (Fig. 34) shows a portion of the window placed in the external cavity wall. This must be large enough to light both the staircase and hall. Additional lighting to the latter is provided by the glazed door and screen, and, if necessary, the door into the kitchen may be partially glazed with figured or similar glass. The cupboard "H" has been omitted for the reason stated below the title of Fig. 32.

*Setting Out and Construction.*—Much of the description on pp. 84 and 87 is applicable. In addition to the net height and going, the position of the half-space landing trimmer will be noted on the storey rod, the width of stairway will be taken and the angles between the walls will be checked.

If a cradle is used to frame the treads and risers together (see p. 87), the two legs will be inclined to conform to the slope of the risers. The strings are fitted to the newels at the shop, they are then dissembled, transported to the job and finally fixed after any necessary adjustments have been made.

CONTEMPORARY TREATMENT.—A more modern treatment of this dog-leg stair is shown in the isometric sketch A, Fig. 35. The balustrades illustrated in the previous figures are of the *open* type, *i.e.*, balusters are employed. These open balustrades are not always favoured, principally on account of the extra labour entailed in dusting, cleaning and polishing. To meet this objection an increasing number of stairs is constructed with *solid* or panelled balustrades. This latter form of balustrade is particularly effective when applied to dog-leg stairs because of its improved appearance compared with the somewhat ugly effect produced by the upper outer string intercepting the lower open balustrade. As this is a matter of opinion, students may draw their own conclusions by comparing the sketch of the open-balustraded dog-leg stair in Fig. 34 with that of the solid-balustraded type illustrated at A, Fig. 35. It must be emphasized, however, that solid balustrades obstruct a good deal of natural light and will cause the interior of a building (especially the hall) to be dark unless larger windows are provided than those which are adequate when open balustrades are employed.

The whole treatment is simple, and therefore elaborately moulded nosings, handrails, etc., must be avoided. The steps may be constructed as shown at F, Fig. 32, or as illustrated at F, Fig. 35, where two alternative nosings are indicated. They are housed and wedged in the usual manner (see F). The strings, which are undressed, are secured to two rough 4-in. by 3-in. posts which are continued and securely fixed to the ground floor and landing trimmers. The ends of the strings are barefaced tenoned to the posts (see J). Note at F that the outer strings are not in the same vertical plane, the inner faces being flush with those of the

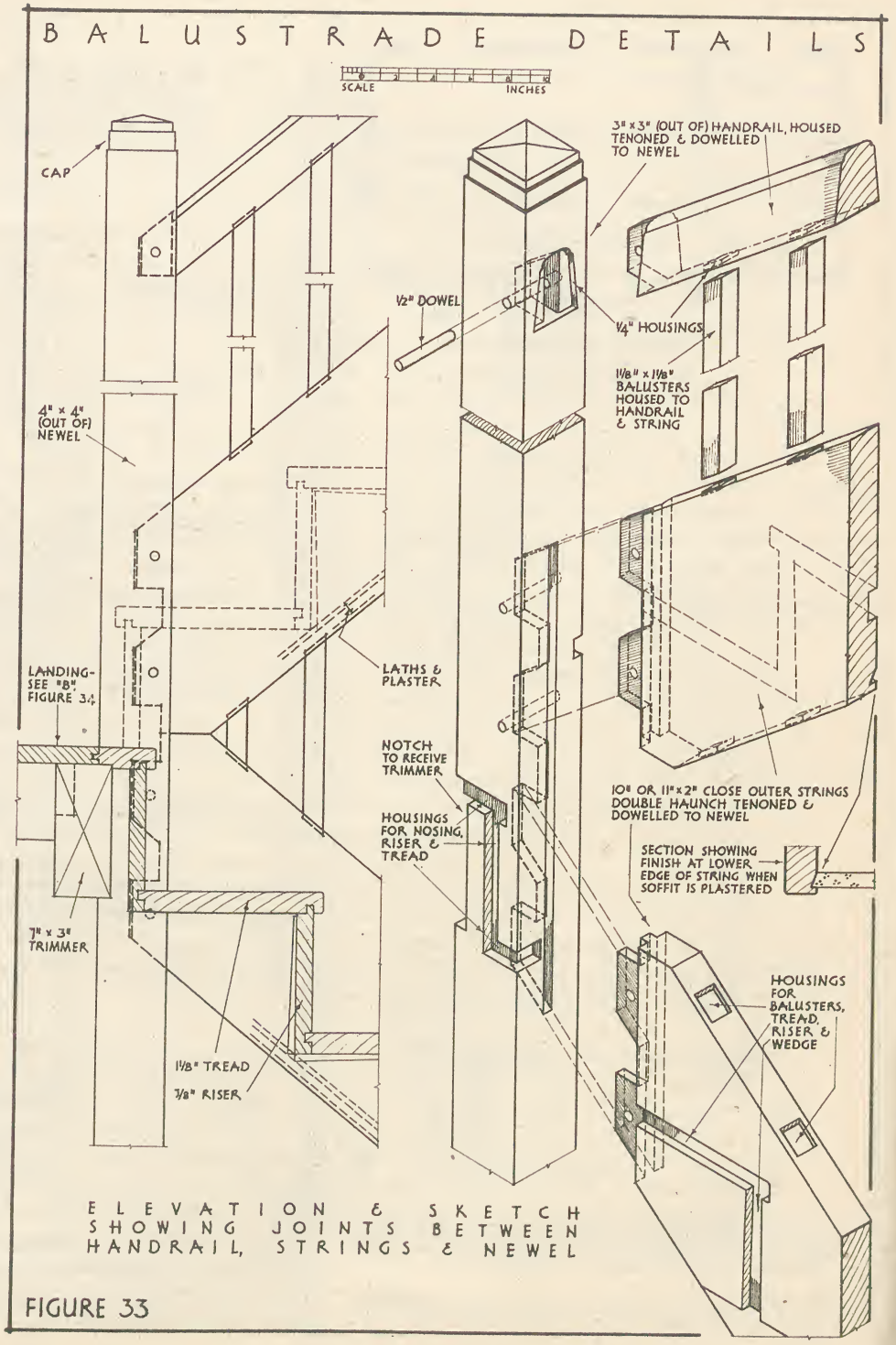
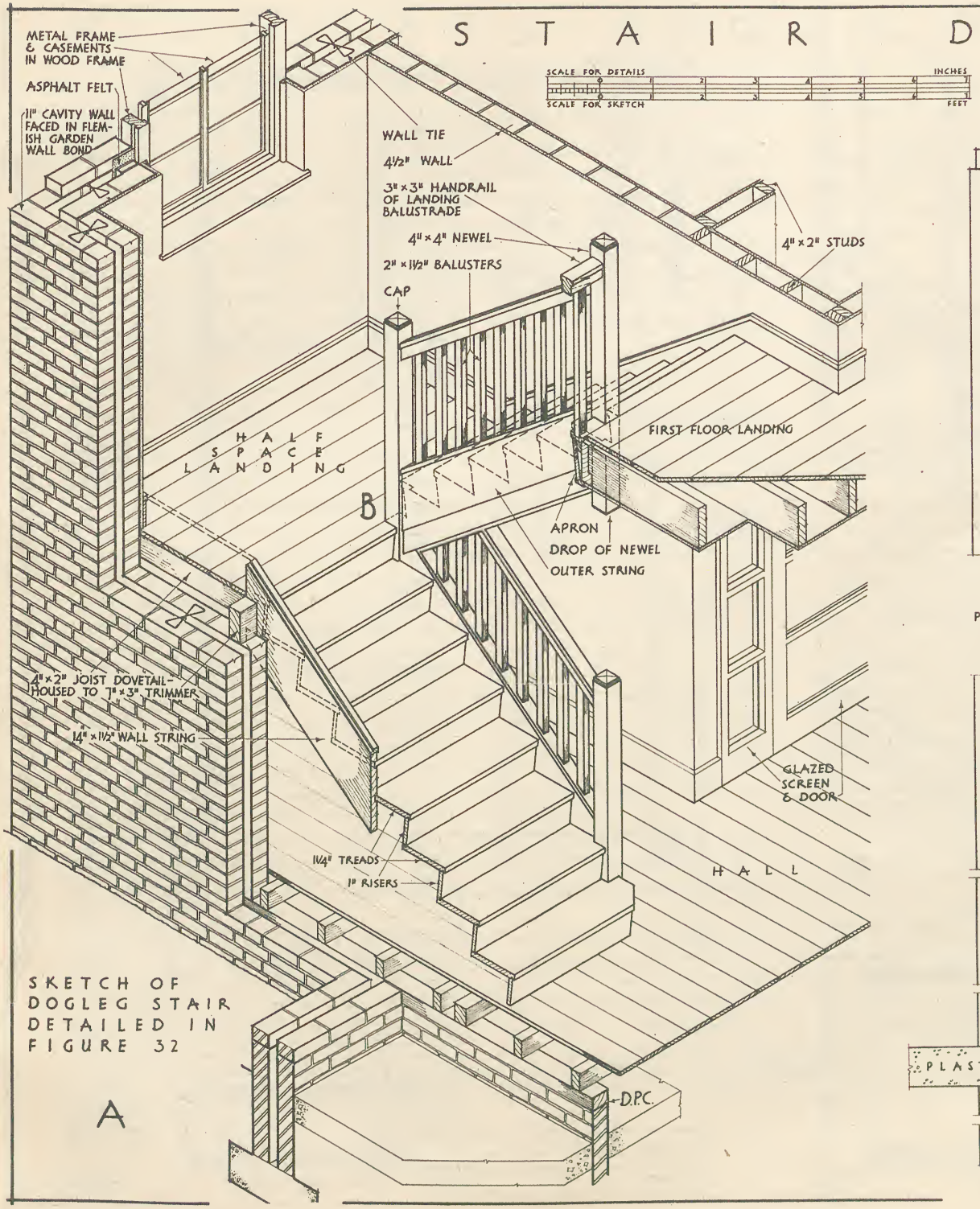

BALUSTRADE DETAILS
SCALE
INCHES
CAP
3" x 3" (OUT OF) HANDRAIL, HOUSED TENONED & DOWELLED TO NEWEL
½" DOWEL
¼" HOUSINGS
1⅛" x 1⅛" BALUSTERS HOUSED TO HANDRAIL & STRING
4" x 4" (OUT OF) NEWEL
LANDING- SEE "B" FIGURE 34
LATHS & PLASTER
NOTCH TO RECEIVE TRIMMER
HOUSINGS FOR NOSING, RISER & TREAD
10" OR 11" x 2" CLOSE OUTER STRINGS DOUBLE HAUNCH TENONED & DOWELLED TO NEWEL
SECTION SHOWING FINISH AT LOWER EDGE OF STRING WHEN SOFFIT IS PLASTERED
7" x 3" TRIMMER
1⅛" TREAD
⅞" RISER
HOUSINGS FOR BALUSTERS, TREAD, RISER & WEDGE
ELEVATION & SKETCH SHOWING JOINTS BETWEEN HANDRAIL, STRINGS & NEWEL

FIGURE 33

# STAIR DETAILS




SKETCH OF DOGLEG STAIR DETAILED IN FIGURE 32

A




## ALTERNATE DETAILS OF BALUSTRADE

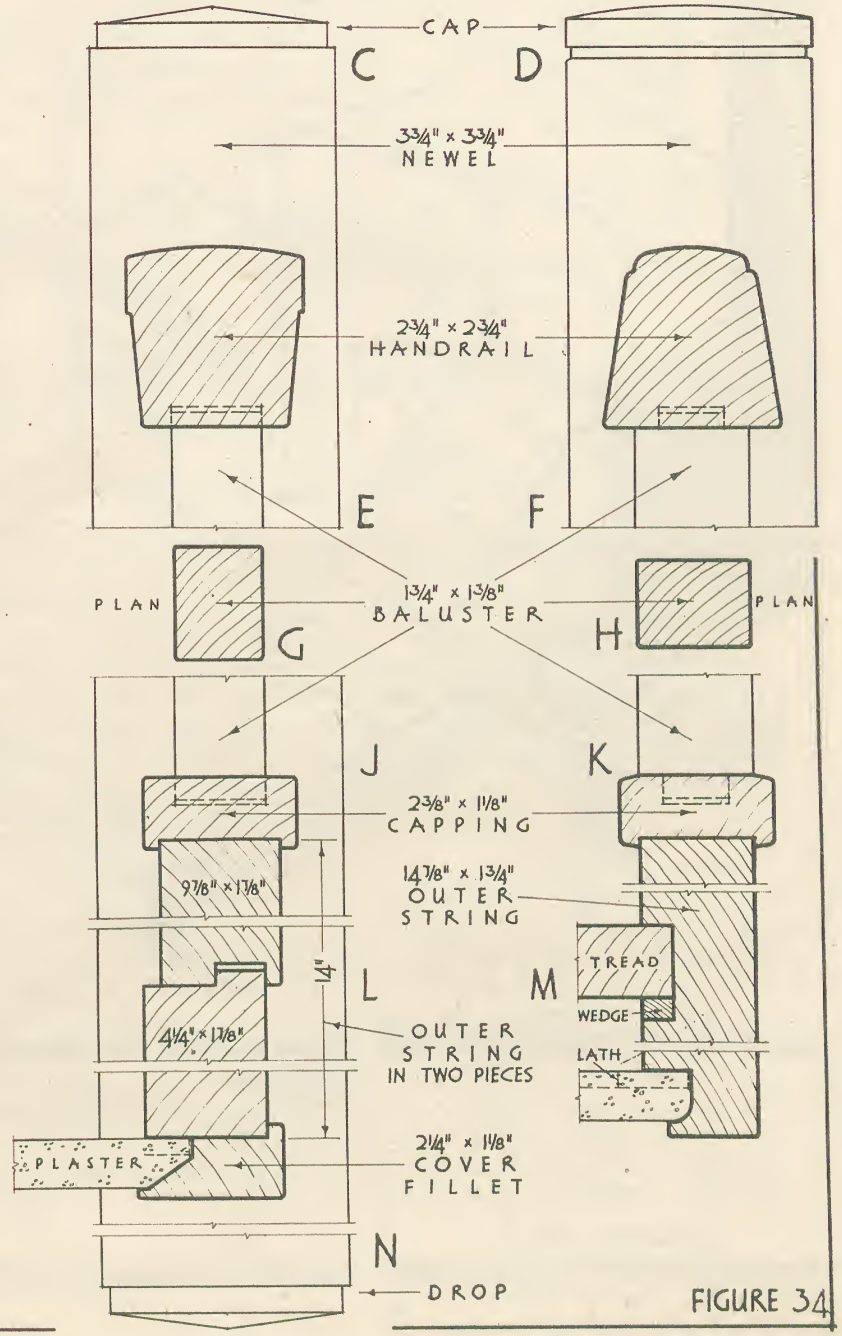
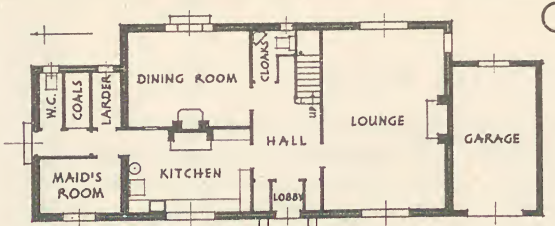
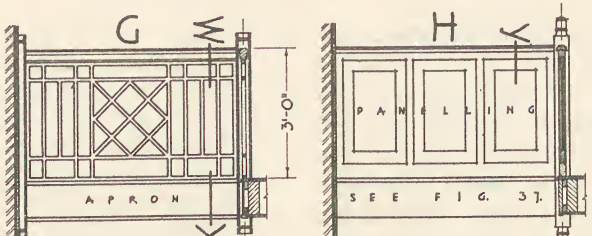



FIGURE 34

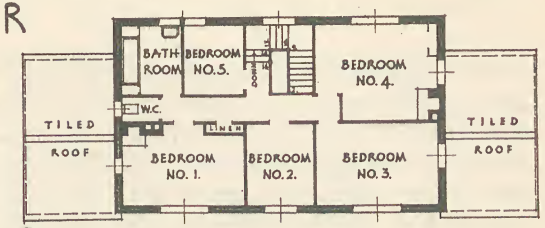
# OPEN WELL STAIR




A KEY GROUND FLOOR PLAN OF HOUSE

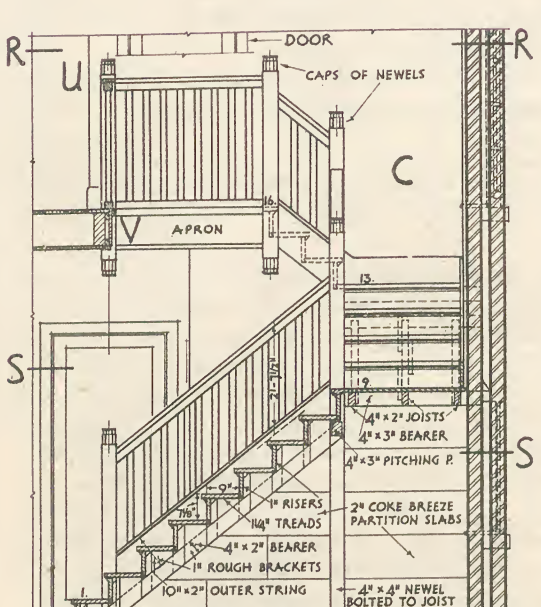



ALTERNATIVE BALUSTRADES AT "T"

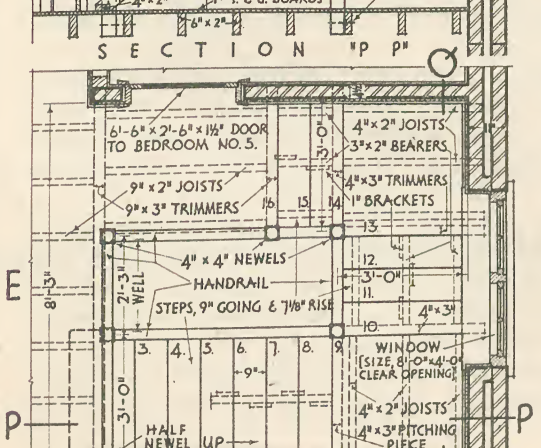



B FIRST FLOOR PLAN

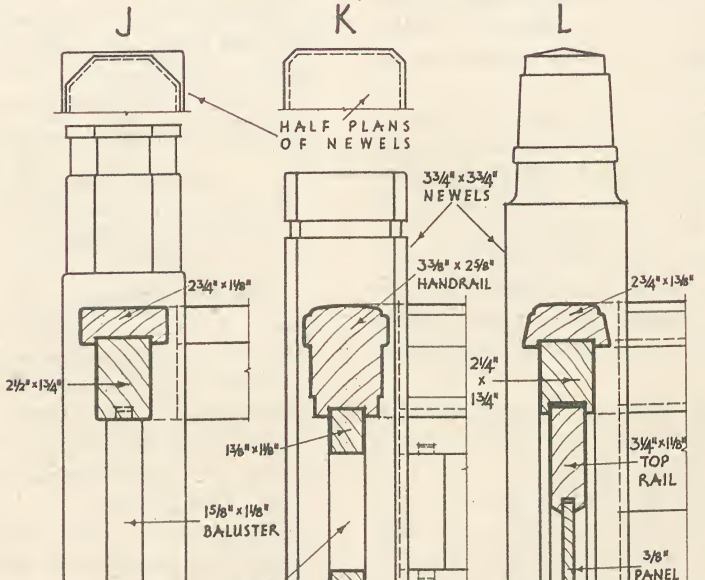
SCALE FOR A & B



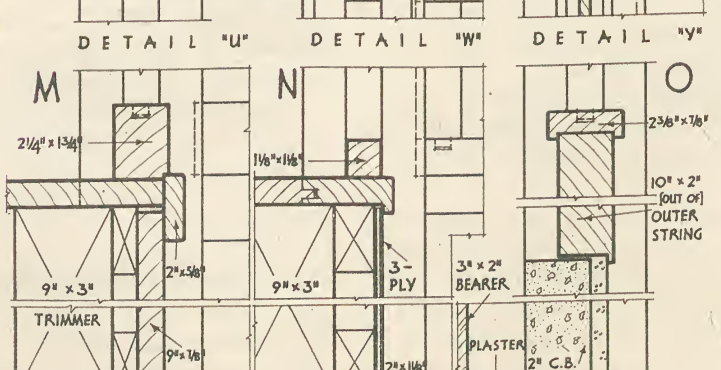

SECTION "P P"




PLAN "R R"



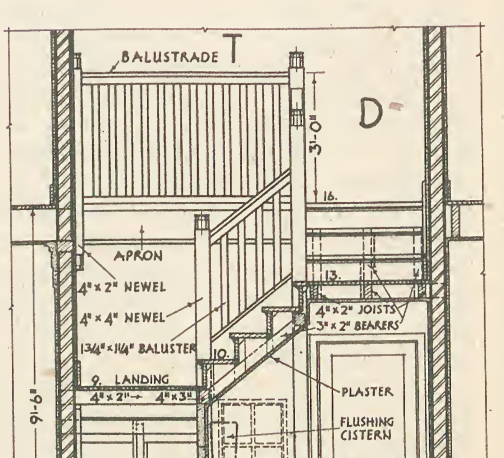

DETAIL "U" DETAIL "W" DETAIL "y"



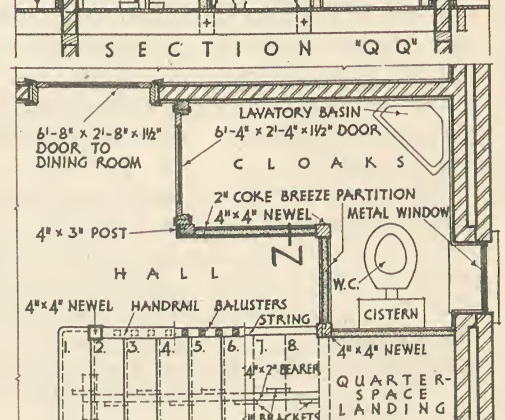

DETAIL "V" DETAIL "X" DETAIL "Z"

SCALE FOR DETAILS

SCALE FOR C D E F G & H




SECTION "Q Q"




PLAN "S S"

FIGURE 36

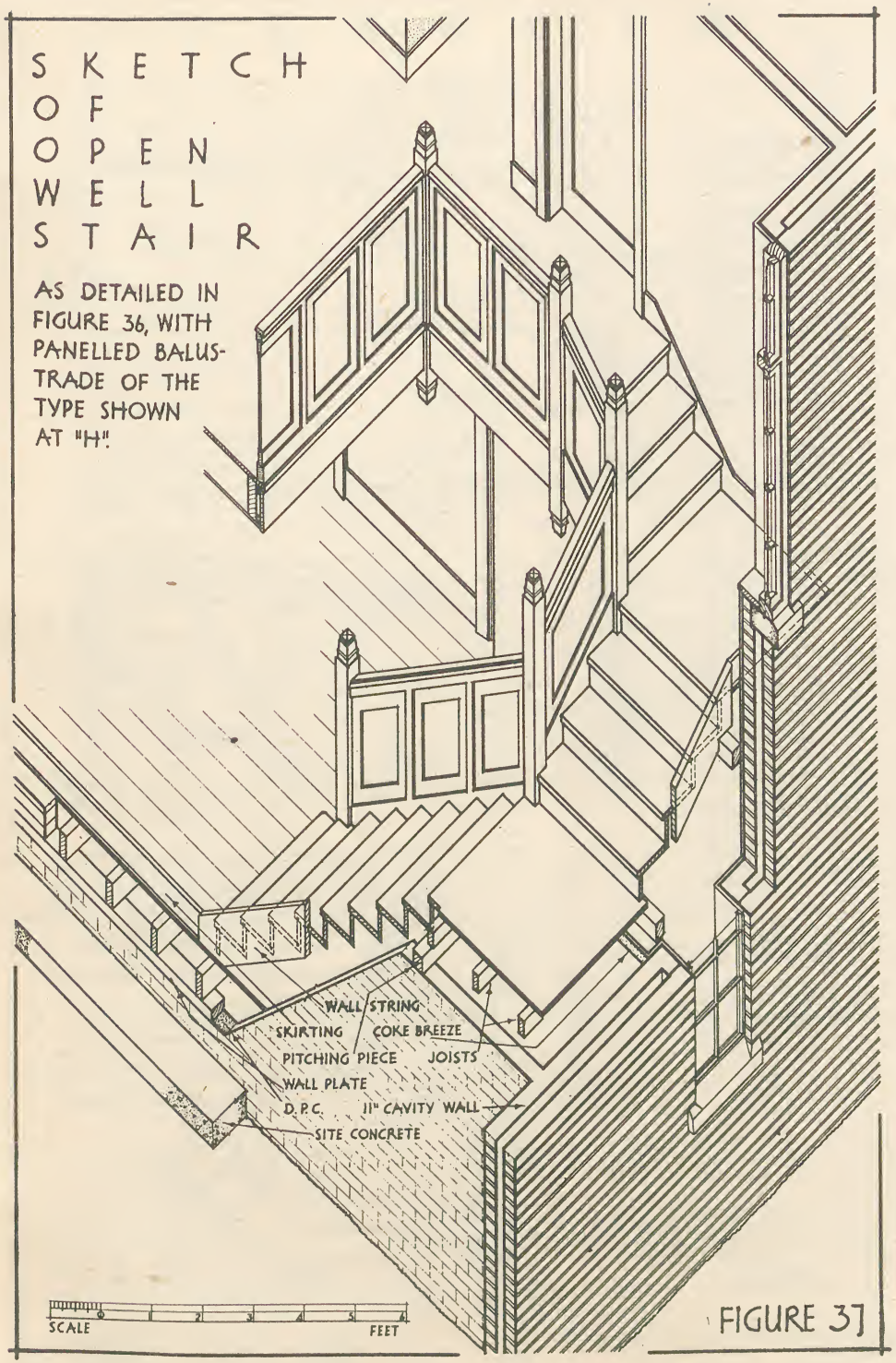



FIGURE 37



broken lines at D) are similar to those shown at D, Fig. 32, Vol. II, because of the restricted headroom.

The open balustrades illustrated in these sections and in previous figures show plain vertical balusters, spaced at 3 or 4-in. apart. Whilst such simple treatment of this type of balustrade is generally preferred, the balusters can be arranged to give a big variety in design. One design is shown at G, Fig. 36, and this is an alternative to the elevation of the balustrade at T (see D). Details of this alternative balustrade are given at K and N. With the exception of that housed into the moulded handrail, the whole of the balusters are out of $1\frac{1}{4}$-in. square stuff, the vertical members being stub-tenoned into the horizontal members.

The application of a solid panelled balustrade to this open well stair is shown at H, Fig. 36. This is an example of framed panelling [1] and is an alternative to the type illustrated in Fig. 35. It shows the balustrade at T divided into three panels. A detail is given at L; the $\frac{3}{8}$-in. thick panels (which may also be of plywood) are framed to top and bottom rails, in addition to vertical members called stiles; the handrail consists of a moulded member surmounting a rail into which the top rail of the panelling is housed. The caps and drops of the newels, moulded from the solid, are more elaborate than those shown hitherto, but a simpler design may, of course, be adopted if preferred.

Some idea of the general appearance of the open well stair detailed in Fig. 36, but with a solid balustrade conforming to the detail at L, may be obtained by reference to the axonometric sketch shown in Fig. 37. When designing a balustrade of this type, it is sometimes difficult to obtain panels of uniform width, although a slight re-adjustment of the position of the newels will assist in avoiding a big variation. Note that a portion of the large window is shown. The need for increased natural lighting when a stair has a solid balustrade is stated on pp. 80 and 90.

The use of laminboard (see p. 103) for the construction of solid balustrades is likely to increase. A detail incorporating this relatively new material is shown at F, Fig. 39. The old-fashioned plain mop-stick handrail has been included, as this affords a firm grip; a moulded rail similar to that at L, Fig. 36, would be equally suitable. The laminboard would be housed into the newels and string.

## WINDERS

Attention is drawn to the references to winders on pp. 80 and 82. The plan of a portion of a stair, having three winders at the foot, is shown at D, Fig. 38. Two sections, an elevation developed from the plan, and a sketch of the necessary framing are also shown.

Treads should be of uniform width, and the going at the "walking line" (which is usually taken to be along an arc struck from the centre of the newel at 1-ft. 6-in. radius) should be at least equal to that of the fliers, *i.e.*, 9-in. One method of setting out the winders on plan is briefly described below D.

[1] See footnote to p. 93.

It will be seen at G, that the 4-in. by 2-in. bearer or carriage cannot be continued to the floor but is supported by a trimmer which is secured to the newel and built into the wall. Therefore, other means of support must be obtained for the winders, hence the provision of a bearer immediately below each of the risers of the second and third steps. As shown at A, C and D, a 3-in. (or 4-in.) by 2-in. bearer, marked " 1," is housed into the newel and wall string, and its outer face is in line with that of the riser of step " 2 " immediately above it (see also G). Similarly, the outer face of bearer " 2 " is directly below that of the third riser. The treads, because of their maximum width, have to be jointed ; these are preferably ploughed and tongued (known also as " cross-tongued ") joints and are shown at A and C and by faint lines at D ; they are similar to those detailed at D and E, Fig. 39. The short returned wall string is tongued and grooved and nailed to the main wall string, the upper edge of which is cut to a curve or easing. These strings must be increased in width to accommodate the winder treads, and the joints between the boards used to build up the string are also ploughed and tongued (see B, C and G).

## SPECIAL STEPS

The bottom step at least of a stair is often specially shaped. This adds greatly to its appearance. Several of these finishes are illustrated in Fig. 39.

SPLAYED STEP.—The application of this step is shown in the part plan and elevation at A and is detailed at D and E. The bottom step projects beyond the newel. Its riser is in three pieces, the vertical edges of which are mitred, ploughed (grooved) and glued hardwood tongued. The nosing of the tread is shaped to conform. The outer ends of the two bottom steps at J, Fig. 29, are splayed and constructed in this manner, and both ends of the two steps at the foot of the central flight at N are similarly treated (see also C, Fig. 29, D, Fig. 32 and A, Fig. 34).

A splayed step may also be formed by constructing the riser as described below.

BULL-NOSED STEP (see part plan and elevation at B and the details at G, H and J).—The round end of the step consists of the riser (which is in one piece and has its thickness reduced near the end to enable it to be bent round a wood block shaped to the required quadrant curve), a shaped scotia board (if required) and the tread shaped at the end to conform. The curved portion of the riser is called a *veneer*, as it serves as a thin covering to the block. Its reduced thickness depends upon the curve ; the sharper the curve, the thinner the veneer ; in the given example the thickness is approximately $\frac{1}{2}$-in., although for clarity this has been exaggerated in the details. The block strengthens the riser and prevents the veneer from being damaged. This block must not be in one piece only, as this would tend to shrink to such an extent as to leave a space between it and the veneer ; the latter would then be readily damaged because of lack of support. Accordingly, the block is built-up of three or more pieces, and, in

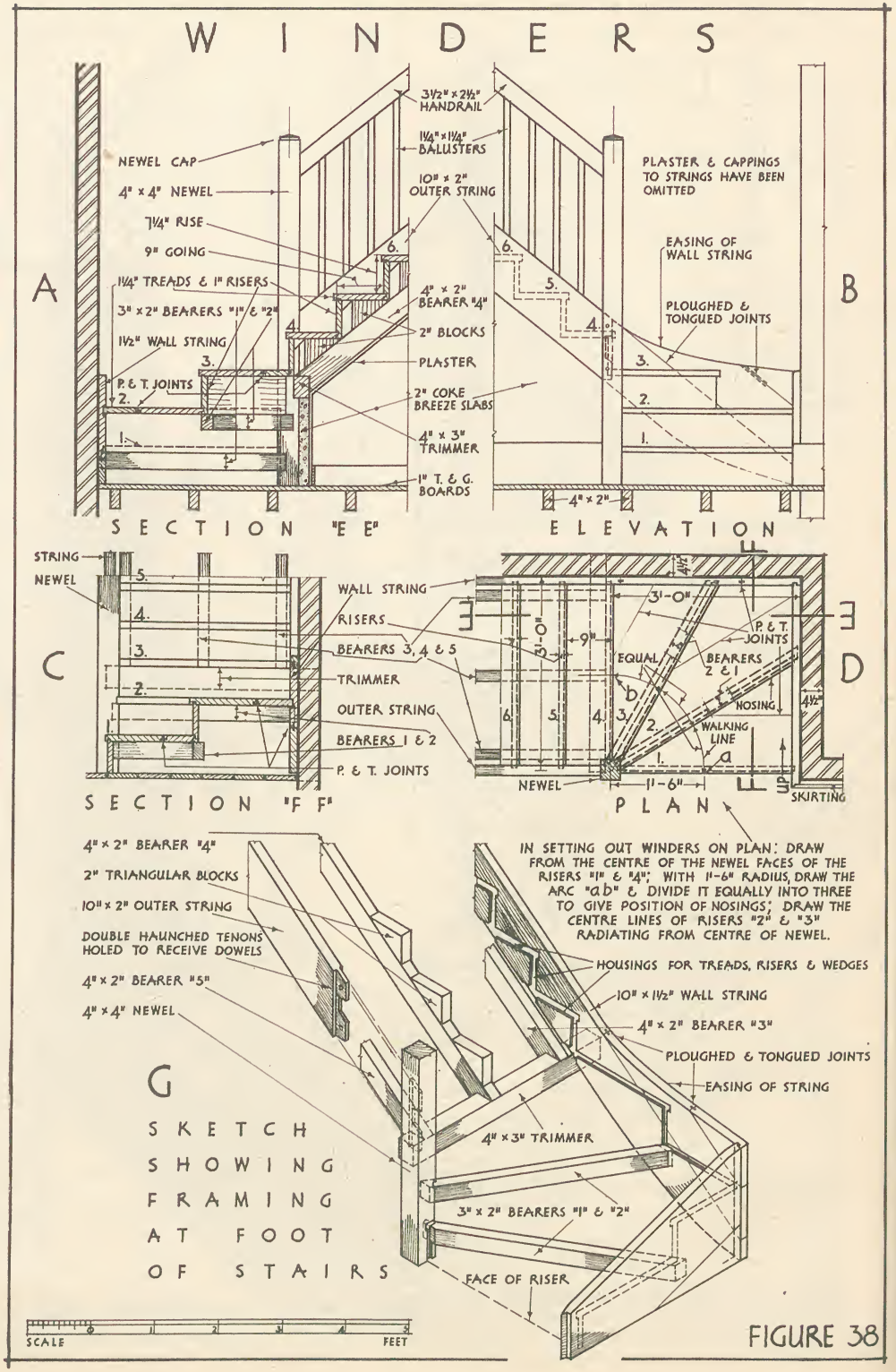



FIGURE 38

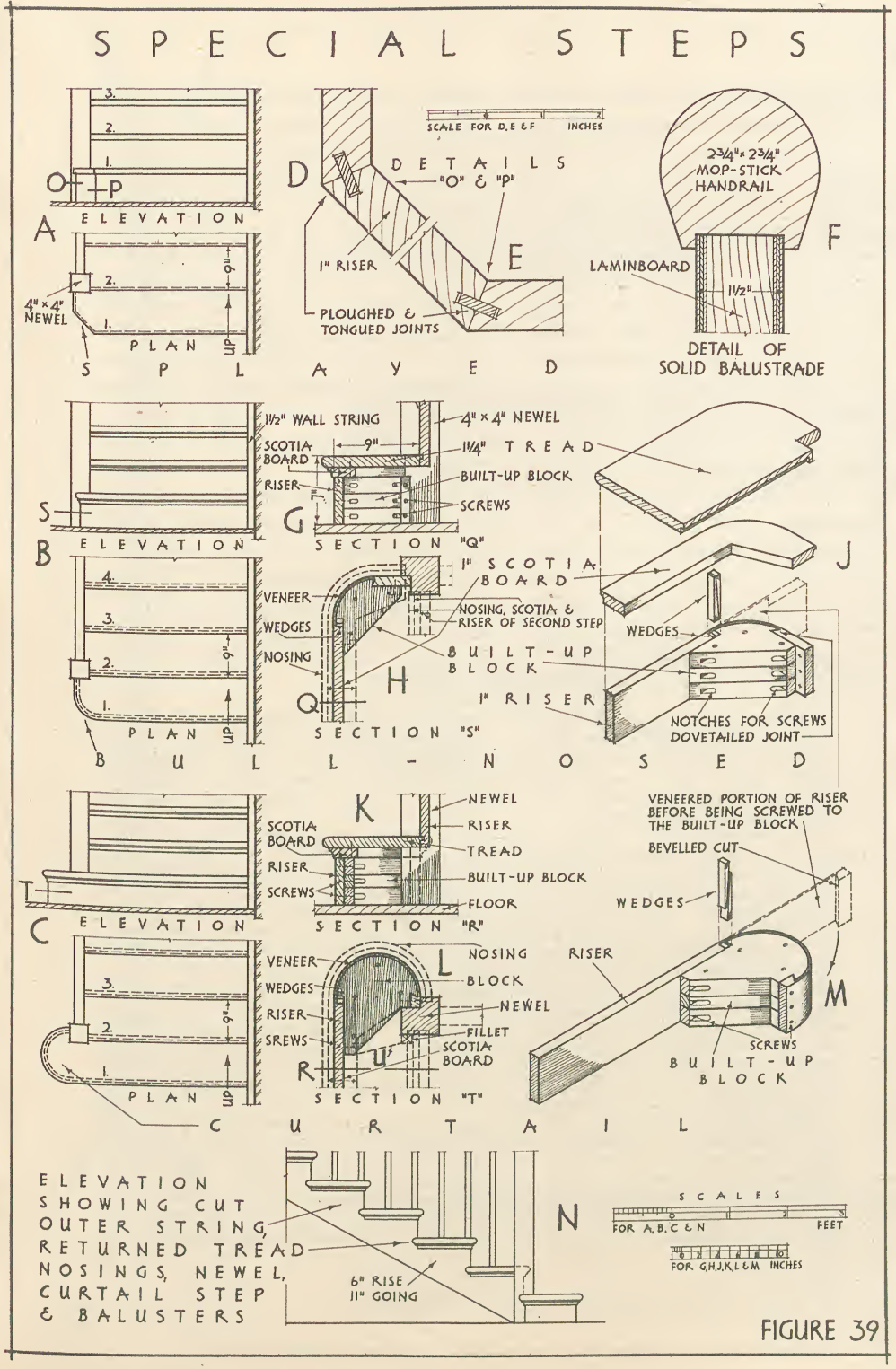



FIGURE 39



order to reduce still further the liability to shrinkage, the pieces are arranged "cross-grained," *i.e.*, the grain of one is opposite to that of the adjacent piece (see J and p. 102).

The step is constructed in the following manner: The block is built-up to the required height by gluing and screwing or nailing the pieces together, the top and bottom surfaces are planed flat and the block is cut to shape, as shown at H and J; the block is double rebated, one edge being square cut and the opposite edge (nearest to the newel) being bevelled cut or dovetailed. The riser (which should be of carefully selected straight-grained timber, free from knots) is then prepared by marking off the position of the bevelled and square cuts, the length of the veneer being found by placing the dovetailed edge of the block opposite to the corresponding mark on the riser and revolving the block on the back of the riser until the square edge of the block rebate touches the riser, which position is then marked; an extra ¾-in. is measured on the riser to provide room for the pair of folding wedges. A marking gauge (see 4, Fig. 67, Vol. I) is now used and the thickness of the veneer marked on the riser. Cuts are made across the back of the riser to form the shoulders, and the chisel and router plane are used to remove the core and form the veneer. The cutting of the veneer is often done on the circular saw and sometimes on the band saw. The shape of the veneered end of the riser, before it has been fixed to the block, is shown by broken lines at J. The back of the veneer and the outer face of the block is then roughened by the toothing plane or file to give a key for the glue. The latter is now liberally applied to the back of the veneer (after its face has been wetted with boiling water) and the face of the block. With the dovetailed shoulder of the veneer engaging in the dovetailed rebate on the block, the riser is pressed against the block; the glued wedges are inserted and driven home in order to bed the veneer tightly on the block, and the latter is secured to the riser by means of screws from the back, the notches for these having been previously prepared.

The scotia board, after being reduced in width and shaped, is screwed to the riser and tread.

The foot of the newel is notched out, as shown, and the riser is screwed to it.

A bull-nosed step is also illustrated at D, Fig. 29, A, Fig. 35 and F, Fig. 36.

CURTAIL STEP (see C, K, L and M).—The construction of this semicircular ended step is similar to that described above. The back of the block is sometimes shaped as shown at U (see L) and a vertical fillet (shown crossed by diagonals) is screwed to it and the newel. The end of a curtail step may also be of a spiral form (see the bottom step at O, Fig. 29). Because of the side projection of this step it should not be used if the width of the floor at the side is restricted.

CUT STRING (see N).—This has been included to show the difference between it and all of the close strings illustrated. The upper edge of the string is notched out to receive the treads, and the moulded nosings are returned. There are usually two balusters per step, with a face of one vertically over a riser. This form of string is considered in detail in Vol. IV, as is the commode step (see F, Fig. 29) which has a curved riser built up with narrow vertical strips covered with a veneer.

Stone steps and stairs are detailed in Figs. 44 and 45, Vol. II, and described on pp. 115 and 117. Details of a reinforced concrete step are given in Fig. 46, Vol. II.

## PLYWOOD

A brief description of the manufacture of plywood is given in Vol. I. As plywood is now one of the most important building materials, and its use, already

extensive, is likely to be still further increased in the future, a more detailed description of its manufacture, characteristics, uses and types is given below.

PLYWOOD or RECONSTRUCTED WOOD or LAMINATED WOOD is a compound wood made up of several thin layers or plies or veneers, glued together under pressure, and usually arranged so that the grain of one layer is at right angles to the grain of an adjacent layer or layers.

A sheet or board of plywood usually consists of an odd number of plies, *i.e.*, " 3-ply," " 5-ply," etc. Those which have more than three layers are known as *multi-ply boards*—see C and D, Fig. 40 (5-ply) and E (7-ply); the number of layers may be increased as desired, but boards having more than nine plies have to be specially ordered.

A 3-ply board consists of two outer or *face plies* with a middle *core*. It is important to observe that these plies are *cross-grained*, *i.e.*, the grain of the core of a 3-ply board is at right angles to that of each of the face plies (see B to E, Fig. 40, and pp. 100 and 102). The thickness of the veneers varies; a $\frac{3}{16}$-in. thick 3-ply board will consist of three $\frac{1}{16}$-in. veneers and is an example of an *equal ply* board (see B); a $\frac{3}{8}$-in. thick board, with the same number of plies, has a $\frac{1}{4}$-in. core and two $\frac{1}{16}$-in. face veneers and is known as a *stout heart* board. An example of a stout heart 5-ply board is shown at D; this $\frac{3}{4}$-in. thick board has two 2·5-mm.[1] thick face plies, a 6-mm. central ply and two 4-mm. intermediate layers or *cross bandings*. Examples of equal ply boards are shown at C and E.

MANUFACTURE OF PLYWOOD.—The various processes are: (1) Preparation of logs, (2) conversion, (3) trimming, (4) drying, (5) gluing, (6) pressing, (7) re-drying and (8) finishing.

1. *Preparation of Logs.*—Logs of certain timber, such as alder, beech, Gaboon mahogany and oak, are first either steamed or boiled to render them pliable. This softening of the fibres takes place in large covered-in concrete pits containing water heated by hot-water pipes situated on the floor; the logs are kept submerged for at least two days—depending upon the size and hardness—until thoroughly saturated. Other timbers, including British Columbia pine and European birch (Finnish, Polish and Russian), do not require this preliminary treatment. The logs are then cross-cut into lengths (7 or 8-ft. or according to the size of the converting machine), the bark is removed by hand or machine (called a *barking lathe*), hard knots are cut out and any irregularities removed.

2. *Conversion.*—The prepared logs are now converted into veneers by either (*a*) rotary veneer cutters or (*b*) veneer slicing machines.

(a) *Rotary Cutting Method.*—More than 90 per cent. of veneers are cut by this method. A *rotary veneer cutter* or *peeler* is a powerful lathe with a very sharp fixed knife slightly longer than the log (see J and K, Fig. 40). The log, prepared as described, is conveyed by a crane to the peeler, lowered and then clamped between two centres or chucks which penetrate the ends of the timber at the " centres " previously marked. The horizontal log is revolved and a continuous ribbon of veneer, uniform in thickness, is cut by the knife and emerges—like a roll of paper being unrolled—between it and the *pressure* or *nose bar*. This bar prevents the wood from splitting, and the distance between it and the knife is regulated according to the thickness of the veneer. Logs converted in this manner should be of large (not less than 10-in.) diameter, straight grained and reasonably free from knots and other defects; the diameter of Gaboon mahogany and Douglas fir (both extensively used for plywood) logs varies from 2 to 6-ft. or more. The veneer deteriorates in quality as the log unrolls owing to the increase in the size and number of the knots towards the centre. Hence the veneer is sometimes increased in thickness as the peeling proceeds and is used for cores, the thinner and better veneers being used as face plies. The peeling process is continued until the diameter of the log has been reduced to about 6-in.

A modification of rotary cutting, used to produce highly decorative veneers from rarer woods, is known as the *half-round* or *stay-log cutting* method. The log is divided longitudinally by means of a circular saw, a half log is secured to a strong bar fixed between the centres of the rotary cutter and with its sawn face against the long knife. Thus, commencing from the heart, a series of veneers is produced as the half log swings round and descends on to the knife. As the conversion is not tangential to the annual rings, the resulting figure is generally richer than that produced by the first method.

(*b*) *Slicing Methods.*—Decorative veneers are obtained from certain valuable richly figured rare timbers by slicing in order that the attractive figure may be shown to greater advantage than that produced by the rotary cutter. Burls, crotches and stumps (see A, Fig. 40 and p. 5) are often converted in this manner. There are two types of machine used for this purpose, *i.e.*, the (i) horizontal veneer slicer and the (ii) vertical veneer slicer.

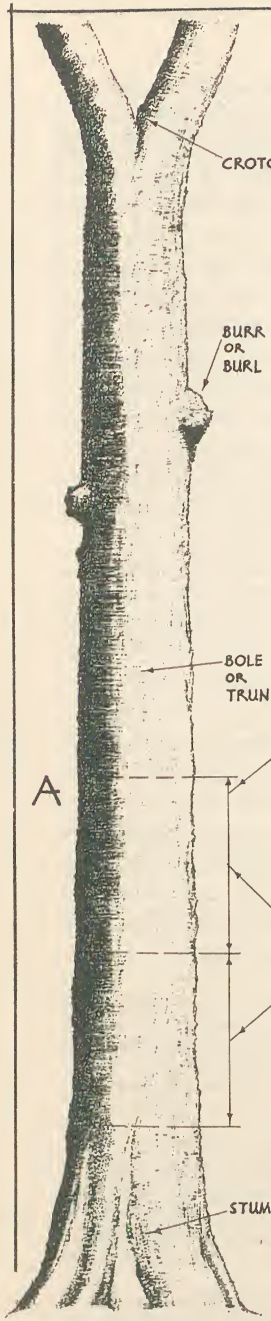
(i) *Horizontal Veneer Slicing.*—The slicer is a heavy, powerful machine which has a fixed bed in addition to a wide knife with pressure bar in a movable frame. The log is divided into two down its length, and one-half is fixed to the bed with the sawn face uppermost and level. The knife cuts the veneer to the required thickness as the frame is forced forward over the fixed timber. During the slicing process the veneer passes upwards between the knife and pressure bar and over the frame. On completion of the cut the knife is returned to its original starting point and the timber is automatically raised by an amount equal to the thickness of the veneer. This process is repeated until the half-log has been converted. The thickness of the veneers varies according to requirements and the nature of the wood, but $\frac{1}{28}$, $\frac{1}{20}$, $\frac{1}{15}$ and $\frac{1}{10}$-in. thick veneers are common. In addition to burls, crotches, etc., boles of satinwood, sycamore, teak, walnut and several other timbers are sliced, as rotary cutting is apt to cause splitting. Each veneer is numbered as it leaves the machine and stacked in that order. This ensures correct matching (see p. 100). Flitches are also converted into veneers by slicing.

(ii) *Vertical Veneer Slicing.*—This machine has a fixed knife and the log is secured to a movable bed. The slicing operation is therefore the reverse to that described above, the veneers being produced as the bed travels along the knife.

The above methods are known as *flat cut* and the veneers show a straight grain on each side of the central heart. Whilst avodiré, silver greywood, Cuban and Honduras mahogany, sapele, and timbers (such as oak) which have the medullary rays well developed, are sliced as above described, more highly figured veneers are

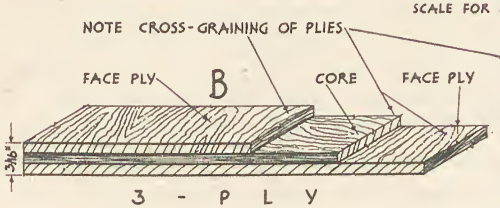
[1] The thickness of plywood imported from continental countries is specified in terms of millimetres; thus, boards from Russia, Finland and Poland are referred to as being 3, 4, 6, 9-mm. etc., thick. A millimetre = 0·039-in., hence 7-mm. = 0·27-in. (approximately $\frac{1}{4}$-in.). American, Canadian and English plywood is specified as $\frac{3}{16}$-in., $\frac{1}{4}$-in., $1\frac{1}{8}$-in., etc., thick boards.

# PLYWOOD ETC

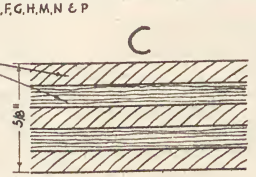



SKETCH SHOWING PARTS OF TREE USED FOR THE CONVERSION OF PLYWOOD

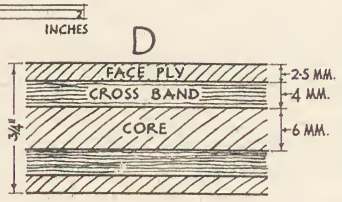
SCALE FOR B,C,D,E,F,G,H,M,N & P



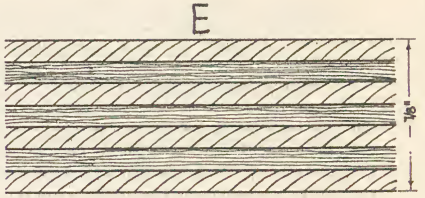

3 - PLY EQUAL



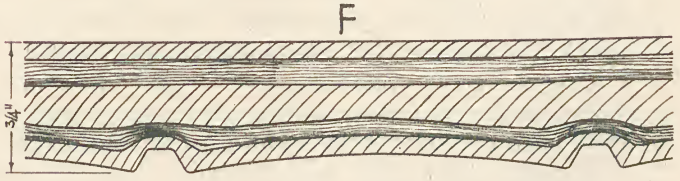

5 - PLY EQUAL



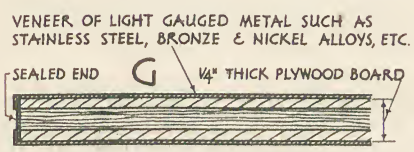

5 - PLY STOUT HEART



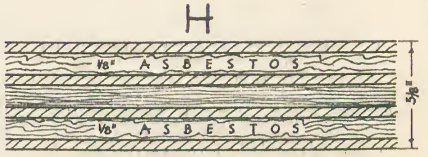

7 - PLY EQUAL



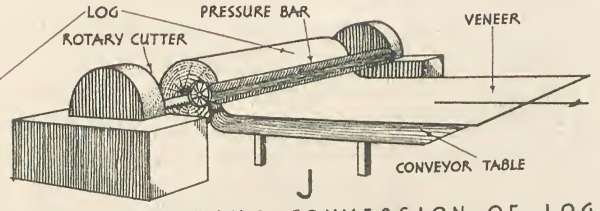

MOULDED PLYWOOD



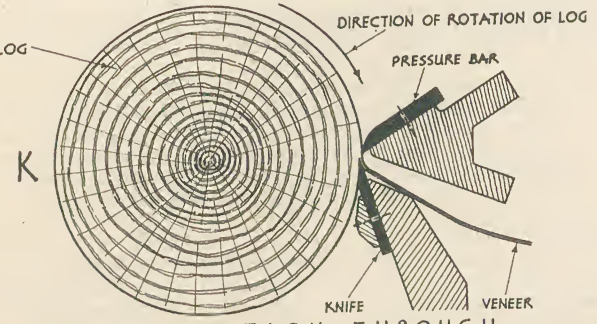

METAL-FACED PLYWOOD




COMPOSITE BOARD




SKETCH SHOWING CONVERSION OF LOG INTO CONTINUOUS RIBBON OF VENEER



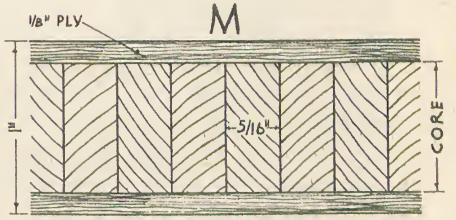

CROSS SECTION THROUGH LOG IN ROTARY CUTTER

## STANDARD SIZES OF PLYWOOD BOARDS

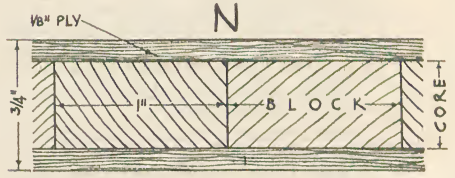
| TIMBER | THICKNESS | NUMBER OF PLIES | LENGTH (INCHES) | WIDTH (INCHES) |
|---|---|---|---|---|
| DOUGLAS FIR (PSEUDOTSUGO TAXIFOLIA) | 3/16", 1/4", 3/8", 1/2". | 3 | 60, 66, 72. | 12, 18, 24, 30. |
| | 1/2", 5/8", 3/4" | 5 | 84, 90, 96. | 36, 42, 48, 54, |
| | 7/8", 1", 1 1/8" | 7 | 102, 108, 120. | 60, 72, 84. |
| REDWOOD (PINUS SYLVESTRIS) | 4 & 5 MM. | 3 | 48, 50, 60. | 24, 36, 40, |
| | 6 MM. | 4 | 72, 80, 84. | 48, 50, 60. |
| | 9 MM. & UP | 5 ETC. | | |
| GABOON (AUCOUMEA KLAINEANA) | 3 TO 6 MM. | 3 | 60, 72, 84, | 36, 48, 60, |
| | 8 TO 16 MM. | 5 | 90, 96, 120. | 72, 84. |
| | 19 TO 22 MM. | 7 | | |
| | 25 TO 30 MM. | 9 | | |
| WALNUT (ENDIANDRA PALMERSTONII) | 3/16", 1/4", 3/8", 1/2". | 3 | 72, 84, 96. | 36, 48. |
| | 3/8", 1/2", 5/8", 3/4" | 5 | | |
| | 5/8", 3/4" | 7 | | |

NOTE: 1 MILLIMETRE = 0·039"

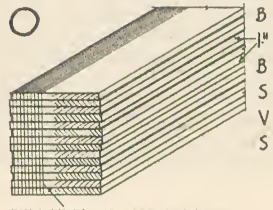
L




LAMINBOARD

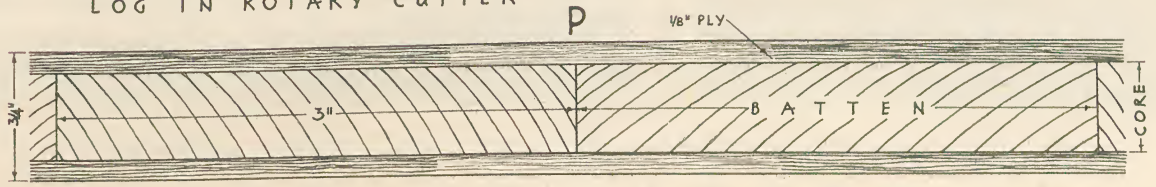



BLOCKBOARD




BALK OF 1" THICK BOARDS SHOWING VERTICAL SAWCUTS

THIN LINES INDICATE SAWCUTS




BATTENBOARD

FIGURE 40

produced when the timber is radially sliced, *i.e.*, the logs are first quartered and each quarter is placed at an angle on the slicer.

Formerly veneers were sawn by either the band or circular saw. Whilst sawing has been largely superseded by slicing, certain few timbers—such as black bean and African mahogany (for curl veneers)—are sawn, as they are difficult to slice.

3. *Trimming.*—As the continuous veneer emerges from the peeler, it either winds on to a spindle which is afterwards taken to the trimming machine, or it is conveyed to the latter along a table which may be some 200-ft. in length. The trimming machine is called a *clipper* or *guillotine* as it consists of a long knife which slides vertically in a frame fixed above and across the conveyor table. The band of veneer passes under this knife and is cut transversely into widths [1] on each descent of the knife. Some cutters work automatically; in another type the knife is caused to drop as the operator in charge of the machine depresses a foot pedal.

In many manufactories the veneers are cut to standard widths and these depend upon the sizes of the presses (see p. 102). Any serious defects, such as splits and large dead knots, are eliminated by cutting off the defective sections.

4. *Drying.*—Veneers for good class work must now be dried to a predetermined moisture content, varying from 4 to 10 per. cent. This is known as the *dry-cemented process*.[2] There are many types of dryers. One of the latest, over 100-ft. long, is heated by hot water or steam pipes and the air is circulated by fans. The veneers are passed in at one end between rollers which propel them at the desired speed—depending upon the thickness of the veneers, desired moisture content, etc.—through the chamber towards the exit, where they are cooled before emerging and then removed by hand. This operation only occupies approximately a quarter of an hour.

*Jointing.*—Veneers required for large panels, sliced decorative veneers and those used for cores are jointed in the following manner: The edges must be perfectly straight and clean to ensure a close joint. Hence the veneers are piled to a thickness of about 1-in., clamped together, and the edge of the pile is sawn by a circular saw and spindle with cutterblock—the latter producing a good finish; in one machine the veneers are held flat on a fixed bed by a heavy clamp and a travelling circular saw, followed by a cutterblock of the spindle, traverses the pile to effect the cut.

The two veneers to be jointed have their opposing edges painted with glue. The sheets are placed flat on the table of the jointing machine, one type of which consists of a series of narrow rollers operating over a heated plate and in front of which is a small rotating wheel which dips into a trough containing a solution of formaldehyde. The sheets are fed towards the machine over the solution wheel which moistens the glued edges, and as they are drawn through the machine between the rollers and plate the edges are forced together to form a tight joint.

In another type of machine, called a *taping machine*, a narrow strip of gummed perforated tape (*kraft tape*) is passed over a heated roller which moistens the glue and is pressed over the joint by a second heated roller. Sufficient glue is thereby forced between the joint. This tape is subsequently removed by damping and scraping.

*Repairing.*—Defects, such as pitch pockets and large unsound knots (especially those liable to become loose) must be removed and replaced with sound veneer. This operation is known as *patching* or *plugging*. The defective portions are removed by a metal hand punch of oval, circular, etc., section which is smartly tapped to give clean cuts. These spaces are immediately filled in with plugs or patches of sound veneer of similar size, shape, colour and grain so as to render the repairs as inconspicuous as possible. The patches have their edges glued prior to placing them in position, after which pressure is applied to make them secure.

5. *Gluing or Cementing.*—The dried veneers are placed on a long belt conveyor and inspected for quality. Those suitable for face veneers and cores are sorted and the sheets are also arranged into sizes. Any defective sheets are sent to be repaired as described above. The sound veneers are conveyed to the gluing machine or *glue-spreader*. This consists of a pair of steel grooved rollers which dip as they rotate into troughs containing the adhesive; these rollers are specially designed to evenly spread the glue or cement over one or both faces of the veneers as they are passed between them. The sheets are placed by hand between the rollers, and, on emerging, are assembled according to the type of press which is to be applied in the next operation.

If cold pressing (see p. 101) is to be employed, 3-ply boards are assembled in the following manner: A 3-in. thick wood board, called a *caul*, of size slightly larger than the sheets of veneer, is placed on a low truck standing at the discharge side of the glue-spreader. A sheet of face veneer (not glued) is placed on the caul with its face-side [1] (or outer surface when assembled) down. The core ply is passed through the machine, which spreads a uniform layer of adhesive on *both* sides. An operator then quickly places this glued core upon the face veneer, taking care that its grain is at *right angles* to that of the face ply. The second face ply is now carefully laid over the core with its face-side up and its grain *parallel* to that of the first face veneer (see p. 98). This operation is repeated until a sufficient number of boards have been assembled to form a pile of about 3-ft. thickness. A thin (about $\frac{3}{4}$-in.) plywood caul is placed between the boards at approximately 1-ft. intervals during the piling, and a thick caul is laid on top of the batch which is at once taken to the press.

A multi-ply board is built up in a similar manner, each *alternate* ply being glued on *both* sides and cross-grained assembled. Thus, a 7-ply board would be assembled in the following sequence: Face veneer (face-side down and longitudinal-grained), glued cross-banding (cross-grained), veneer (longitudinal-grained), glued core (cross-grained), veneer (longitudinal-grained), glued cross-banding (cross-grained) and face ply (face-side up and longitudinal-grained).

[1] The length is in the direction of the grain and the width is tangential to the grain.

[2] Some Russian manufacturers still practise the *wet-glued process*, *i.e.*, the sheets are not dried prior to gluing; the sheets having a high m.c. are glued, assembled and hot pressed. Such plywood boards are only suitable for inferior work.

[1] During conversion in the rotary cutter, the fibres on the concave or inner surface of the veneer tend to separate longitudinally; such splits do not extend to the convex or outer surface and are called *checks*. These are unavoidable if the thickness of the veneer exceeds $\frac{1}{16}$-in. Therefore, if the outer veneer is placed "face-side down," as stated above, any checks will be concealed. The outer surface is marked during the cutting operation to ensure correct assembly.

A sheet of veneer straight from the rotary cutter will assume a curved shape. If the sheet is pressed flat the outer surface will be subjected to a compression strain and the inner surface will be under tension which tends to cause the fibres to separate. The term "tight-cut" is applied to the outer surface of a veneer and "loose-cut" to the inner.

Boards which are to be hot pressed (see next column) are assembled in a similar manner, but thin aluminium or zinc cauls are generally used instead of plywood cauls and two are placed between each board.

This gluing or cementing process is one of the most important in the manufacture of plywood. An inferior or unsuitable adhesive will cause plywood to be a most unreliable building material, even if best quality timber is employed. The plies must be strongly united together and must remain so when subjected to atmospheric conditions. The production within recent years of waterproof adhesives has been largely responsible for the high repute now held for the better graded plywood.

The adhesives used in plywood manufacture are: (1) Resin, (2) casein, (3) animal and (4) soya bean glues or cements.[1]

1. *Resin Cements.*—Such are chemically produced, and carbolic acid (phenol) and formaldehyde are in common use in the preparation of what are known as *phenolic resins*. One group of these resins is obtained in liquid form ready for use and applied as described on p. 100. They are also available in a fine powder form to which a solvent, such as alcohol, is added as required. Another group resembles sheets of tissue paper; these solid thin films consist of sheets of paper which have been impregnated with the phenol-aldehyde solution. A film, cut to the required size, is placed between each pair of plies whilst being assembled and then taken to a hot press (see next column); the intermediate process of gluing already described is thereby eliminated.

These are reliable waterproof adhesives (*i.e.*, they will not decompose under the action of water), they are not liable to the attack of micro-organisms; are fire-resisting, do not stain the wood and have great strength. Resin adhesives are employed in the manufacture of all good class plywood where durability is an essential requirement. They are more expensive than the following adhesives.

2. *Casein Glues.*—Casein is a milk derivative. Rennet, or acids such as hydrochloric, is added to skim milk to hasten the separation and precipitation of the curd. The latter is finely ground after it has been washed, pressed and dried, and borax or other chemicals are added. It is obtained in powder form.

The merits of casein glue are its great strength and it is applied cold in the glue spreader or by a brush. The disadvantages are its liability to stain certain hardwoods, such as oak and mahogany, and whilst it is highly water resisting, it is not entirely waterproof.

3. *Animal Glue*, commonly known as *Scotch glue*, is prepared from the skins and bones of cattle, horses, etc. The skins are steeped in liquid lime for two or three weeks, washed, dried and the glue (glutin) is extracted by boiling; this glue is very strong. The bones are cracked in a mill, placed in benzol or other solvent to remove the fat, taken to a steam boiler where the glue is extracted, and finally purified by heating with alum, etc.

Animal glue is prepared for use by softening it by several hours immersion in from two to three parts cold water; it is then melted by heating in water-jacketed glue pots. It is applied hot at an approximate temperature of 140° F.

The better grade glue has great strength, but it is neither water nor heat resisting, and it is liable to the attack of micro-organisms. It does not stain the wood, although care has to be taken when applying it to sycamore, maple, and similar light-coloured timbers to prevent discoloration.

4. *Soya Bean or Oil Seed Residue Glue.*—This is derived from Manchurian soya beans, cotton seeds and peanuts. The oil is extracted and refined. It is obtained in white powder form to which water is added. Carbon disulphide is added to increase its water-resisting quality; the glue is not entirely waterproof. Owing to its alkaline nature, it is apt to stain woods containing acid (*i.e.*, oak). It is applied cold and is extensively used for Douglas fir veneers.

*Vegetable Glue and Blood Albumen Glue* are also used. The former is derived from tapioca starch and is applied cold; it is not waterproof. The latter glue, produced from blood obtained from slaughterhouses, is used in conjunction with casein; it is applied hot, and whilst it is not absolutely waterproof it is highly water resisting. Both glues are liable to stain certain hardwoods.

6. *Pressing.*—The glued plywood boards must now be subjected to the necessary pressure to effect a sound bond between the glued sheets. This operation takes place in either a cold press or a hot pressure machine. These machines are operated by hydraulic power.

*Cold Pressing.*—The cold press has a movable lower cast iron plate (called a *platen*) which operates between four corner vertical pillars secured at the base and supporting a heavy iron headpiece. Both the top of the platen and the underside of the headpiece have machined flat surfaces. The pile of glued boards, assembled between the thick cauls, as described in the previous operation, is placed in the centre of the press upon transverse steel beams laid at intervals on the platen; a similar number of steel beams is placed on the top caul and immediately over the lower beams. The press is now operated, the platen being raised by hydraulic rams to bring the upper steel beams in contact with the headpiece. As the pressure is gradually increased, operators fix vertical clamps or turn-buckles to the projecting ends of the steel beams; each pair of beams (the lower and upper) is thus connected by two clamps. When the desired pressure has been reached—indicated by a pressure gauge—the clamps are uniformly and finally tightened. The platen is then lowered and the batch, *still clamped*, is removed to the drying room; the clamps are not removed until the glue has set.

The maximum pressure and the time during which the boards are clamped depend upon a number of factors, such as the type of glue used, the area and thickness of the boards, the nature of the wood and the moisture content. Thus, valuable decorative veneers, casein glued, may only be subjected to a maximum pressure of 80-lb. per sq. in. for two hours in order to avoid staining; ordinary commercial plywood batches, soya bean glued, may be subjected to a maximum pressure of 150-lb. per sq. in. and the clamps should not be removed within eight hours. The normal practice is to leave the clamped batches overnight and to remove the clamps during the following morning.

*Hot Pressing.*—Resin cemented and hot glued plywood boards must be hot pressed to ensure a strong bond between the plies; some manufacturers also use hot presses for casein glued boards.

A hot press consists of a bottom metal table, pressure head and a dozen or more intermediate hollow steel platens spaced at regular intervals. Not more than two assembled boards, with their zinc or aluminium cauls (see preceding column), are placed between each pair of platens, and the latter are heated by steam admitted to them through flexible-jointed pipes. The press is then closed,

[1] A liquid glue sets when the excess moisture is removed by pressure, but will re-absorb moisture and is therefore not waterproof. A cementing material, such as one of the resin adhesives, does not absorb moisture and is accordingly waterproof. In the plywood industry the words " glue " and " cement " are now considered to be synonymous.

*i.e.*, the bottom table is raised, and this in turn lifts the platens and reduces the spaces between them; the pressure is increased until the boards are subjected to that required. Meanwhile the heat from the platens is transmitted to the plywood to effect a strong bond between the glued surfaces of the plies. The pressure is maintained for several minutes, this "bonding time" being variable according to the type of glue employed, nature of the wood, etc.

The temperature varies from 140° F. (for animal glued boards) to at least 360° F. (for certain resin cemented boards). The pressure also varies between 150 to 300-lb. per sq. in. There is also a big variation in the size of presses; thus, one standard size of birch plywood from Russia is 56-in. by 56-in., and the largest press in this country produces 200-in. by 72-in. boards.

On removal from the press the plywood boards are sticked (see p. 8), *i.e.*, pieces of 1-in. square laggings (or sticks or skids) are placed at intervals between the boards and directly over each other; the latter is necessary to ensure flat boards. A heavy steel beam is placed on top of the pile.

7. *Re-drying.*—The boards absorb moisture during the gluing and hot-pressing processes and the moisture content must therefore be reduced. Hence the sticked piles from the hot press are taken to a re-drying chamber and the m.c. is reduced to the desired percentage—usually 8 per cent. Cold pressed boards, after the clamps have been removed (see p. 101), are sticked and the piles re-dried. This operation must not be hastened, otherwise the boards will be permanently warped or twisted.

8. *Finishing.*—After re-drying the edges are trimmed as the boards are accurately sawn to the desired length and width. There is a considerable variation in the sizes. Examples of stock sizes of two softwood and two hardwood plywoods are listed at L, Fig. 40. Special sizes can be obtained.

Finally the plywood boards are planed and sanded to remove surface imperfections and give a smooth finish to both sides. The planing machine or *scraper* has a fixed knife at the bed of the machine (see p. 28) and the boards are fed between rollers against it, one side being scraped at a time. Boards which have been patched (p. 100) are not scraped. The sanders are of the drum and belt types (see p. 30).

Merits of Plywood.—1. The shrinkage and expansion of best grade plywood is almost negligible. *This is due to its cross-grained construction.*

It is stated on p. 7 that the maximum shrinkage of timbers occurs in the tangential direction (*i.e.*, in the direction of the annual rings) and that longitudinal shrinkage (*i.e.*, in the direction of the grain) is very small indeed. Thus, an unrestricted sheet of rotary-cut veneer will *work* (*i.e.*, shrink or expand) in its width and there will be comparatively little movement in its length. When, however, the sheet is one of several forming a plywood board it is restricted, and accordingly movement is considerably reduced. Thus, the tendency for the core of a 3-ply board to increase or decrease in width as the humidity changes, is practically neutralized by the two face veneers to which it is securely glued; the face veneers, having the grain at right angles to that of the core, will not move in the direction of the width of the core and will therefore restrain the latter. Similarly, any tangential movement of the outer plies will be restrained by the longitudinal grain of the core,

2. A plywood board is stronger than a piece of unlaminated timber of the same area and thickness. This is also due to its cross-grained construction.

The tensile strength of wood is much greater with the grain than across it, and its shear strength across the grain greatly exceeds that with the grain. Hence, as a well-constructed board of plywood has the grain of one ply at right angles to the grain of adjacent layers, maximum strength in both the width and length of the board results. Further, certain cements, such as resins, increase the strength of plywood.

3. A plywood board, because of its cross-grained construction, does not readily split when nailed near to its edges.

This is a decided merit, especially if used for wall panelling when the boards are secured to grounds by panel pins along the edges. Unlike plywood, an unlaminated piece of wood tends to split along the grain.

4. As rotary cut plywood can be obtained in large sizes, it may be applied as wall panelling without recourse to framing composed of rails and stiles. Hence the modern tendency to use this product for this purpose in order to obtain large flush surfaces.

Prior to the introduction of rotary cutting the width of solid wood panels was restricted because of the limitations of timber, and therefore framing formed an essential feature of traditional panelling.

5. The modern trend of using thin veneers, instead of relatively thick panels and framing, for panelling, furniture, etc., has resulted in the economical employment of rare and valuable timbers.

Perhaps the only demerit of plywood is the unattractive figure of most timbers when rotary-cut, although this does not apply to certain timbers, such as birch and Queensland walnut. As already stated (p. 98), veneers of many timbers are sliced in order to show the grain to the best advantage.

Uses of Plywood.—It is used extensively for (*a*) covering or panelling walls (see Fig. 35), partitions and ceilings, (*b*) doors (see Fig. 25), (*c*) stair balustrades (see Fig. 35) and (*d*) furniture. Its use as a floor covering has already been referred to (p. 40). It is being used to an increasing extent for temporary work, such as shuttering for concrete. It is also in big demand for railway coach, bus, motor car, etc., construction. The cheaper varieties are used on a large scale for boxes, chests, barrels, etc.

Moulded Plywood.—A development of ordinary plywood is that which is moulded on one surface. Such is used for decorative wall panelling. There is a wide range of patterns, one of which is shown at F, Fig. 40.

The moulded surface is formed in the press. The plain board, having been glued and assembled as described on p. 100, is put into the press. A metal or solid wood mould (called a *form*), having a surface shaped to the reverse of that required on the board, is placed on top of it, and the moulded contour is imparted to the upper surface when pressure is applied.

Plywood boards can be bent to concave and convex curves by machinery and other means (including the vacuum process). These methods are discussed in Vol. IV.

Metal-faced Plywood.—Another development is the plywood board faced on one or both sides with metal. The metals employed are aluminium,

bronze alloys (such as gilding metal), nickel alloys (*i.e.*, monel metal), galvanized and stainless steel, etc., and the sheets are rolled to a very thin gauge. The metal is bonded to the plywood by special waterproof cements. When metal-faced on both sides, the edges of the boards are sealed (one finish is shown at G, Fig. 40) in order to exclude moisture and prevent corrosion of the inner surface of the metal.

Metal-faced plywood is used for wall panelling (single metal faced), counter tops (bars), partitions between public bath and water closet cubicles, etc. The metal increases the rigidity of the boards, preventing buckling, and it can be easily cleaned. Metal angles are used as a protection at the edges and external angles of counters, panelling and laminboard (see below); these, in addition to narrow vertical, etc. metal bands when inlaid flush with (or screwed to) the plywood surface, provide an effective treatment to wall panelling, counter fronts, etc.

LAMINBOARDS or LAMINATED BOARDS (see M, Fig. 40) are a development of plywood and are used extensively for panelling, furniture, partitions, doors (see H, Fig. 25), etc. A laminboard consists of a core built up of thin strips or slats (or laminæ) not exceeding 7 mm. ($\frac{5}{16}$-in.) wide and glued between two or more outer plies. The slats are glued together and, as in plywood, the grain of these core slats must be at right angles to the adjacent plies. The strips forming the core are cut from built-up sheets which have been rotary cut (see p. 98).

The following is a brief description of the manufacture of laminboards: The peeled veneers, having been cut to width and dried to 7 to 10 per cent. m.c., are glued and assembled to form a pile of approximately 2-ft. thick (80 veneers of $\frac{5}{16}$-in.) between two thick cauls (p. 100). Only every alternate sheet is passed through the glue-spreader. The pile is taken to the press and clamped as described on p. 101. The adhesive is usually casein, and the pile (or "block" or "balk") is generally cold pressed. The balk is then converted into slabs of various thicknesses (see next column) by passing it through a frame saw or a horizontal or vertical band saw, the cuts being at right angles to the layers—similar to O, Fig. 40. Two or more slabs are edge glued to form the necessary width of core, which is then re-dried to the required m.c., planed to the necessary thickness, and finally glued (resin adhesive may be used), assembled between the two or more face plies (which have been previously jointed to the required width), pressed, re-dried, trimmed and sanded as previously described.

The standard dimensions of laminboards vary with different manufacturers, a common size being 6-ft. long, 16-ft. wide and $\frac{1}{2}$ to 2-in. thick.

BLOCKBOARDS.—These resemble laminboards, the only difference being in the construction of the core which is built up with blocks of wood not exceeding 1-in. wide (see N, Fig. 40). They are cheaper than laminboards and are used for similar purposes, although laminboards are preferred for first class richly veneered work.

With exception of the preparation of the core, the various operations of manufacture are similar to those of laminboard. Logs from which the timber is obtained for making the cores are converted into boards by a large vertical band re-saw (see p. 6). These boards are at least 10-in. wide and approximately 1-in. thick. The boards must be carefully seasoned and dried to the required m.c. (4 to 7 per cent.); the ends are then cut by a cross-cut saw and any large knots or defective portions are removed. The boards are assembled into piles, the lengths being built up as required and the joints staggered. Gluing, re-assembling, pressing, sawing (see O, Fig. 40), re-drying and planing operations are carried out, care being taken in re-assembling to ensure that the *boards are arranged heart side to heart side in pairs to neutralize warping* (see p. 8). The cores are then glued, assembled between the outer plies, pressed, etc.

The standard sizes of blockboards are similar to those of laminboards.

BATTENBOARDS (see P, Fig. 40).—With exception of the core these are similar to blockboards. The core is comprised of close-grained battens, not exceeding 3-in. width, which are edge glued. They are not used extensively in this country, laminboards and blockboards being preferred.

COMPOSITE BOARDS.—A composite board consists of several wood plies with one or two layers of asbestos fibre (p. 121) or other insulating material (see H, Fig. 40). Asbestos is a good non-combustible and sound insulating material, and it is light in weight. The sheet of asbestos is soaked in weak glue size, dried, and casein glued between sheets of wood ply. When used for covering ceilings, walls and partitions, this material renders rooms cooler in summer and warmer in winter, reduces sound transmission (p. 49), and is relatively non-inflammable.

CHAPTER THREE

# ROOF COVERINGS

*Syllabus.*—Manufacture and characteristics of clay and shale plain tiles, pantiles, Italian, Spanish and interlocking tiles ; eaves, ridge, hip, valley and verge details ; vertical tiling. Concrete tiles, asbestos-cement tiles and corrugated sheets, corrugated iron sheets. Stone slating. Shingles. Copper and zinc details.[1]

## PLAIN TILING

THE subject of plain tiling is introduced on p. 141, Vol. I.

MANUFACTURE OF CLAY AND SHALE PLAIN TILES.—The several processes of tile manufacture are similar to those employed in the production of bricks (see pp. 1-11, Vol. II). These processes are (1) preparation of the earth, (2) moulding, (3) drying and (4) burning.

1. *Preparation.*—The machinery required to reduce the clay or shale to a fine plastic condition depends upon the nature of the material. Thus, a soft plastic clay may be brought to a satisfactory condition by passing it through crushing rolls and a pug mill, whereas hard clays and shales may require to be crushed, ground to a powder in an edge-runner; screened, mixed with water and passed through a pug mill. This machinery is described on p. 2, Vol. II. The material is then soured for the reasons stated on p. 4, Vol. II ; that used for hand-made tiles being sometimes left to mature for at least a year before being used.

2. *Moulding.*—Like bricks, tiles are (*a*) hand-moulded and (*b*) machine-moulded.

(a) *Hand-moulding.*—A wood mould, similar to that described for bricks (p. 4, Vol. II), is used. The standard size of a hand-made tile is 10½-in., by 6½-in. by at least ½-in. thick (see E, Fig. 41), and the mould is of these dimensions, plus shrinkage allowance. Both sand-moulding and slop-moulding are carried out. Blocks of the prepared clay, approximately 12-in. by 9-in. by 9-in., are taken as required to the moulder's bench and sliced by means of a taut wire by the boy assistant into *bats* or *clots* which are at least ⅝-in. thick. The moulder takes a bat, sands or waters it, dashes it into the sanded or wet mould and forms the tile in the manner described for brick manufacture (p. 4, Vol. II).

The nibs may be formed in the mould when suitably shaped at one end for the purpose or by bending over projecting pieces formed at the end. If the nibs are of the continuous type (see K, Fig. 41) the mould has one end higher than the rest of the sides, and when the strike used to level the surface is worked towards it, an increased thickness of clay occurs at the high end and this is consolidated to form the nib.

The two holes are formed by the use of a *punch* consisting simply of a piece of wood in which there are two projecting pins, placed at the required distance apart, which are pressed into the clay. Another device consists of a hinged arm having a specially shaped free end with two projecting pins. Both the nibs and holes are formed when the arm is rotated and the free end is pressed into the raised edge of the clay slab in the mould.

The slab is turned out of the mould on to a sanded board. The set or camber is then imparted by piling six of the moulded slabs with heads and tails alternating on to a three-legged stool or *horse* which is convex-curved to the required radius of the camber. A two-handled wood block, having its lower surface curved to the reverse of the horse, is then brought down several times on to the batch. The cambered tiles are then stacked and dried. Alternatively, the slabs from the mould are stacked to a height of about 2-ft. on a *pallet* consisting of 3-ft. long laths spaced at intervals and nailed to the concave-curved top edges of two end cross-bearers which are about 13-in. long. The stack is weighted with a couple of bricks, and the tiles gradually assume the desired shape.

Special tiles, such as purpose-made hip and valley tiles and bonnet hip tiles, are usually hand-moulded.

(b) *Machine-moulding.*—Tiles made by machinery are either wire-cut or pressed.

Wire-cut tiles, like bricks of this class (p. 3, Vol. II), are produced by a pug mill or auger having a die or mouthpiece similar to that shown at A, Fig. 1, Vol. II, but with a cross-section conforming to that of tiles. A continuous thin band of clay is extruded through the die and passed over rollers to the cutting table where it is cut transversely by wires spaced at tile-length apart in a frame. Nibs are produced by a special attachment on the auger which may take the form of an indented roller fixed in front of the mouthpiece, the nibs being formed at intervals on the extruded column of clay. Nail holes may be formed

[1] Asphalt covered flat roofs are detailed in Vol. IV.

by a lever-operated punch containing two pins and fixed as an extension to the cutting table. The nibbed and holed slabs are then stacked on curved pallets, cambered and dried.

Plain tiles are moulded by the pressure process as explained for bricks (p. 3, Vol. II), the die-boxes being, of course, of the appropriate shape and size. The nibs are formed by the plunger as it descends and presses each slab. Holes are formed automatically when the plunger is released.

3. *Drying.*—The drying of bricks is described on pp. 5-6, Vol. II, and much of this may be applied to tiles. Artificial drying is chiefly employed, although hand-made tiles are often allowed to dry gradually on racks by the natural process. There are several methods of stacking the tiles when artificially dried. In one, the tiles are placed upon pallets (see p. 104), each of which holds four tiles. The pallets are stacked in rows one above the other in the drying shed or chamber to a height of at least 5-ft. Moisture is gradually eliminated from the tiles as the heated air circulates round them. Natural drying (p. 5, Vol. II) is still adopted, but on a comparatively small scale.

4. *Burning.*—After being properly conditioned the tiles are stacked and burnt in kilns of the intermittent, continuous and tunnel types (see pp. 6-11, Vol. II). The form of setting varies, depending upon the type of kiln. If it is continuous, it is usual to set the tiles in *cupboards* one above the other. A cupboard consists of four fireclay slabs, one at the bottom and two vertical side slabs which support that at the top. Each holds about twelve tiles placed on edge at nib distance apart to permit of the circulation of the hot gases.

*General.*—Tiles should be well burnt throughout, free from firecracks, dense and tough, and should show a clean fracture when broken. A well-burnt tile is generally indicated by a clear ring when it is struck with a metal bar ; a dull note suggests an underburnt or cracked tile.

Although machine-made tiles from reputable firms are of excellent quality, it is generally considered that hand-made plain tiles are tougher and more durable. Machine-made tiles are more liable to lamination, a defect described on p. 14, Vol. II.

The appearance of sand-moulded hand-made tiles, due to the slight irregularities in shape and a rough textured surface, is superior to that of the regular shaped and smoother surfaced tiles made by machinery. In this respect they also resemble bricks (see pp. 3 and 13, Vol. II). This texture is imparted to the tiles by the coarse sand used to cover the mould and bats ; the sand is impressed when moulded, and during the burning process particles drop out, leaving the characteristic and much-desired roughness of surface. Some machine-made tiles are sand-faced by the several methods described on p. 13, Vol. II. Like bricks, tiles are now produced in a wide range of colours (see pp. 12 and 13, Vol. II).

TESTS.—In accordance with the British Standard Specification for " Clay or Marl Plain Roofing Tiles," No. 402—1930, tiles must comply with three tests, *i.e.*, transverse, freezing and permeability.

The transverse test consists of applying the load from the machine along the centre line at right angles to the length of the tile which has been immersed in water for twenty-four hours and which is supported on the rounded edges of wood bearers placed at 7½-in. centres. Six tiles are tested, and the average breaking load shall not be less than 175-lb. for hand-made tiles and 125-lb. for machine-made tiles.

The freezing test is applied in the following manner in an apparatus similar to that described on p. 15, Vol. II : Four tiles are immersed in water for twenty-four hours, wrapped in a wet cloth and suspended in the freezing solution, consisting of 4 parts ice to 1 part salt (by volume) for twenty-four hours. The tiles are removed, thawed in water for twenty-four hours and again immersed in the freezing mixture for twenty-four hours. This process is repeated ten times, after which the tiles shall not show signs of cracking, laminations and pitting.

The permeability test is determined in an apparatus similar to that described on pp. 14 and 15, Vol. II. Three tiles are tested in the manner there stated, and the average rate of flow through the specimens at the end of twenty-four hours shall not exceed that indicated by a rate of flow of 4-in. per min. along the glass capillary tube of 1-mm. bore under a head of 8-in.

## PLAIN TILING DETAILS

The terms used in slating are also applicable to tiling. Students are therefore referred to Chapter V (pp. 132-141), Vol. I, for definitions of these terms, for a description of the groundwork and for the introduction to the subject of plain tiling.

The various tiles used in plain tiling are illustrated in Fig. 41. According to the B.S.S., No. 402—1930, the standard size of plain tiles is 10½-in. by 6½-in. (see E and K) by a minimum thickness of ½-in. when hand-made and ⅜-in. when machine-made. Some tile manufacturers make 11-in. by 7-in. and 10-in. by 6-in. tiles, and the thickness of hand-made tiles may be as much as ⅝-in. Normally, each tile has two or three short nibs or stubs (see E and L) or a continuous nib as shown at K ; tiles without nibs can be obtained. Each tile is pierced with two holes. The object of the camber to which plain roofing tiles are shaped (see F) is to cause the tails of the tiles to closely contact those under them and thus assist in preventing the entrance of driven rain and snow. In addition to this longitudinal camber, some hand-made tiles are *hatched*, namely, are given a slight curve in their width. Whilst such hatched tiles enhance the appearance of a roof on account of the small undulations produced, rain and snow can be more readily driven up between them.

In the above-mentioned B.S.S. it is specified that the small nibs shall be at least ¾-in. wide and ⅜-in. minimum to ½-in. maximum deep. Continuous nibs must be at least ¼-in. and not more than ½-in. deep. The holes must not exceed ¼-in. diameter at 1-in. minimum to 1¾-in. maximum from the sides and not more than ⅝-in. from the underside of the nibs. The camber or set of hand-made tiles shall be $\frac{3}{16}$-in. minimum and $\frac{7}{16}$-in. maximum, and that of machine-made tiles shall be ⅛-in. minimum and ¼-in. maximum.

Special short tiles are manufactured for eaves and ridge courses and wide tiles for verges and certain hips and valleys. Thus the *eaves under tiles* (see G) are 6½ to 7-in. long by 6½-in. wide and form the bottom course of a double eaves course. The *ridge under tiles* (see H) are 9-in. long and 6½-in. wide and are

used to maintain the normal gauge at the ridge instead of the longer (10½-in.) tiles which had to be cut for this purpose. The *tile-and-a-half tiles*, as implied, are one and a half times wider than the normal tile and are therefore 10½-in. long and 9¾-in. wide (see L). As explained later, they are employed at gable verges, bonnet hips, and swept and laced valleys.

Like slates, plain tiles are laid in regular bond (see J).

LAP, GAUGE AND PITCH.—In Vol. I it was stated that the lap for a slated roof should be 3-in. when the pitch was 30°. For smaller units, such as plain tiles, the lap usually employed is reduced to 2½-in., and the gauge is therefore

$$\frac{\text{length of tile} - \text{lap}}{2} = \frac{10\frac{1}{2} - 2\frac{1}{2}\text{-in.}}{2} = 4\text{-in.}^{1}$$

This reduced lap necessitates a corresponding increase in the *minimum* pitch of plain tiled roofs to 45°. This slope should, however, be avoided, as a 45° pitched roof presents a very unsatisfactory appearance, which is especially noticeable at gables. The draughtsman should therefore refrain from using the 45° set square when designing a roof, even if this causes inconvenience, especially when an adjustable set square is not available! Hence, for æsthetic reasons, the desired minimum pitch is considered to be 47½°. A more pleasing effect is produced when the pitch is between 50° and 55°, and for narrow gables the roofs can, with advantage, be increased in pitch to 60°. The area of a roof, and therefore its cost, is increased as the pitch increases. If, for reasons of economy, a 45° pitch cannot be exceeded, it is recommended that, rather than adopt this angle, the pitch be reduced to 42½° or even 40°, and the lap increased to at least 2¾-in. The pitch of plain tiled roofs, including sprocketed portions (see next column), should not be less than 40°, as the water does not get away quickly on flat pitched surfaces, and on north-east slopes especially the tiles are liable to lamination on account of slowness in drying. If roofs are likely to be exposed to exceptionally severe weather conditions, it may be necessary to increase the lap of the tiles to 3 and sometimes 3½-in.

NAILING.—Copper or composition nails (see p. 134, Vol. I) should be used. Normally, 1½-in. long nails are used, but for thick hand-made tiles the length should be increased to 1¾-in.

As plain tiles have nibs which enable them to be hung on battens, it is not necessary (except as stated below) to nail every tile. *For normal exposures, it is usual to specify that every tile in each fourth or even fifth course shall be twice nailed.* In fairly exposed situations every third course of tiles may be nailed. In very exposed positions, especially if the roofs are steeply pitched and hand-made tiles (the nibs of which are often misshapen and afford an insecure grip) are to be employed, it may be necessary to have every tile nailed. Further, *all* tiles must be twice (and sometimes thrice) nailed which comprise double eaves courses (both the under tiles and those immediately above them), verges, hips (including those adjacent to the hip tiles), valleys (including the tiles each side of purpose-made valley tiles, those adjacent to the tile-and-a-half tiles employed in laced valleys, and those required to form swept valleys—see Fig. 42) and ridge under tile courses.

[1] It will be noted that, unlike that for head-nailed slates, the gauge *includes* the portion of tile between the holes and the head.

BATTENS.—It is common to specify either 2 or 1½-in. by 1 or ¾-in. sawn redwood battens at gauge centres secured with galvanized wire nails. Counter-battens are usually of 2-in. by 1 or ¾-in. redwood spaced at 15 to 16-in. centres and nailed. The length of nails should be twice the thickness of the battens, thus 2-in. nails are used for 1-in. thick battens and 1½-in. nails for ¾-in. battens.

EAVES DETAILS.—A simple open eaves is detailed at C, Fig. 41. This shows the spars at a pitch of 50° overhanging an 11-in. cavity wall. The groundwork consists of battens only, and the underside of the tiles is torched. Alternatively, untearable felt (see p. 136, Vol. I) may be nailed direct to the spars, as shown at A. Counter-battens, as shown at D, may also be employed. In addition to the double eaves course the tiles are shown nailed at every fourth course, which, as explained in the preceding column, is the usual practice. The eaves under tiles are shown to be nibless and fixed with their backs lowermost to ensure a close contact between the tiles in this double course; the common practice is to fix the under tiles as shown at D.

The detail at D shows a sprocketed closed eaves having a minimum depth at the gutter which, in most cases, is a desirable feature. The spars are pitched at 55° and, for the reasons already stated, the sprockets are given a 40° pitch. The sprocket reduces the rate of flow of water which in a storm, and when the roof is steeply pitched, would tend to overshoot the gutter. The bell-shaped finish also enhances the appearance. Whilst a slightly flatter pitch of 35° (90° − 55°) may be preferred (see L, Fig. 37, Vol. I), it is emphasized that the normal minimum pitch of any part of a plain tiled roof is 40°, and if this is to be reduced (especially at the eaves where the water passing over it may be considerable) the materials and workmanship must be of the best quality and the lap should be increased beyond 2½-in. The tiles are shown nailed at every fifth course, which agrees with the minimum requirements (see preceding column). The groundwork complies with that advocated for best work, namely, boarding (covered with bituminous felt), counter-battens and battens. The soffit is closed with 9-in. by ¾-in. boards nailed to 2-in. by 1½-in. brackets fixed to the spars, and a narrow fascia (backed by a tilting fillet) finished flush at the soffit. A simple quadrant bead is scribed to the wall and nailed to the soffit boards. As an alternative to previous details, the wall plate is shown bedded on the outer leaf of the wall, and in order to immediately distribute part of the weight transmitted from the roof to the inner leaf, a header course is shown below the wall plate (see p. 42 and B, Fig. 13, Vol. II). The cast iron gutter would be supported in the usual manner either by straps screwed to the backs of the spars or brackets secured to the fascia (see M and N, Fig. 75, Vol. I).

The many alternative eaves details given in Vol. I, in addition to those in Fig. 13, Vol. II, and Figs. 15, 17 and 18 in this Vol. (modified to suit the pitch) may be adopted.

# PLAIN TILING

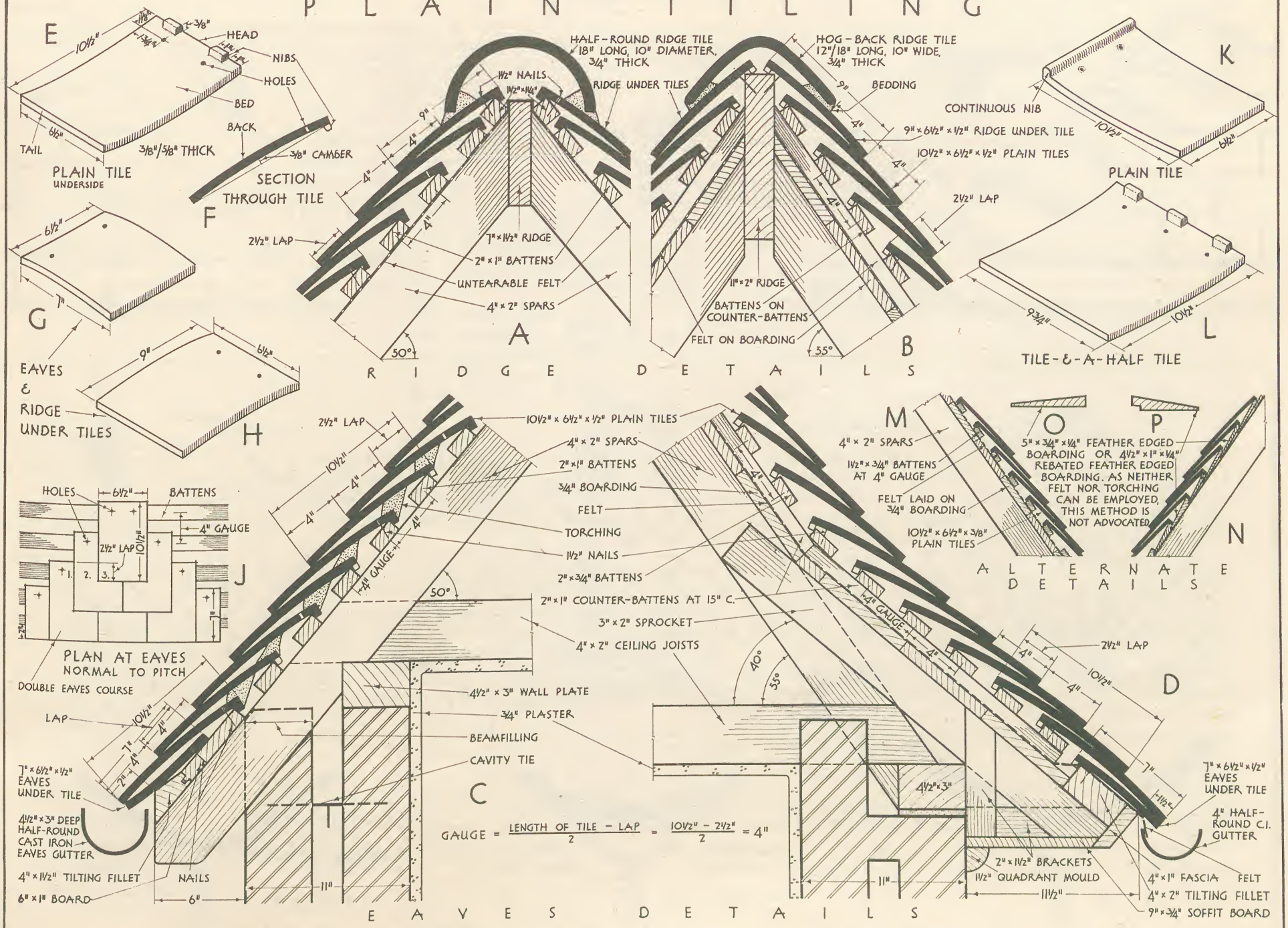
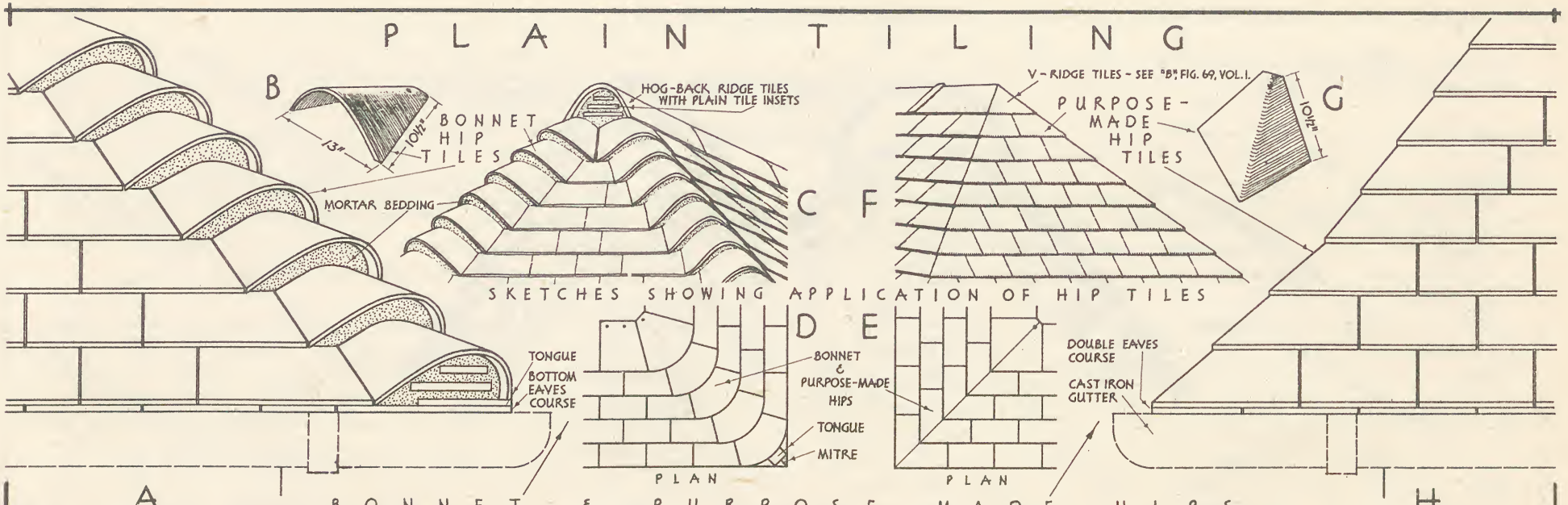
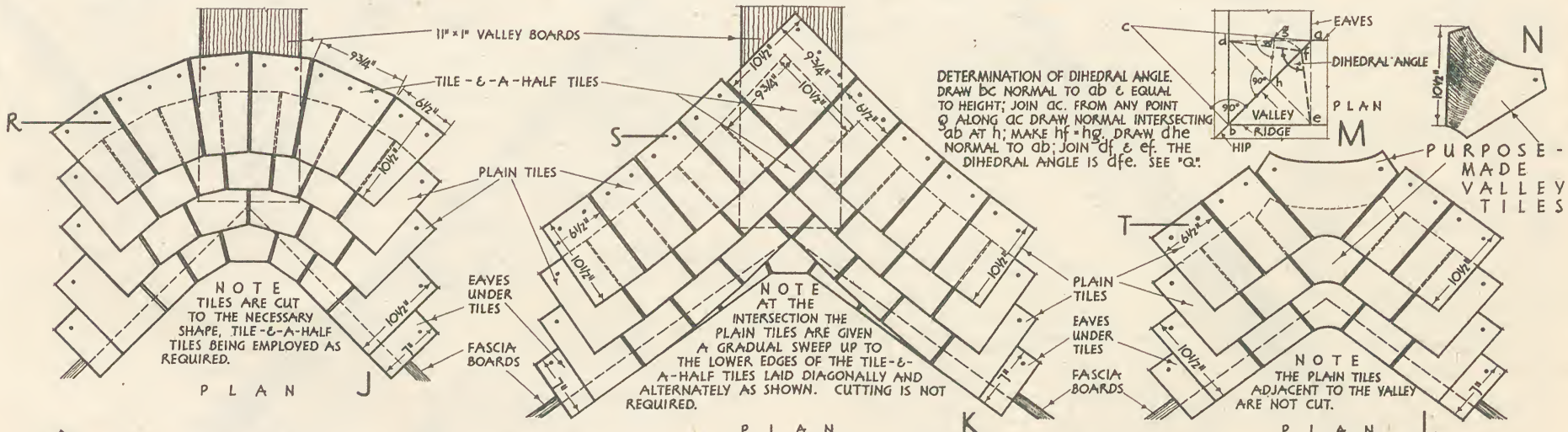
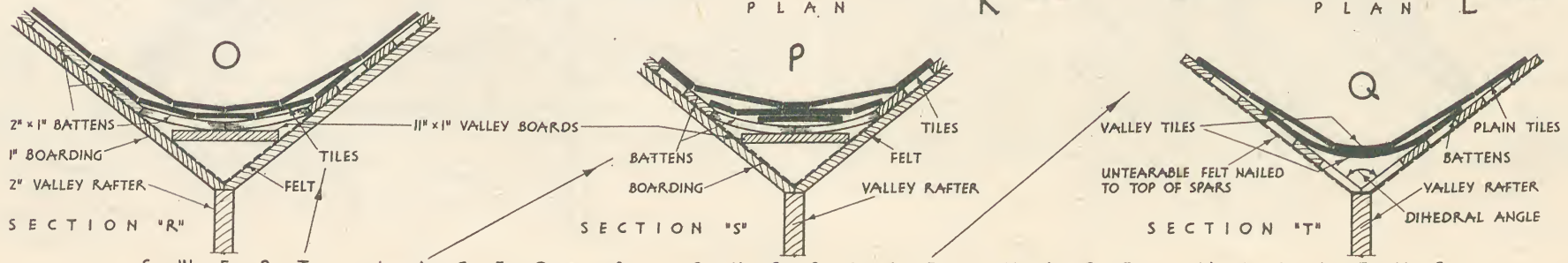



FIGURE 41

# PLAIN TILING




SWEPT, LACED & PURPOSE-MADE VALLEYS

NOT TO SCALE

FIGURE 42

RIDGE DETAILS.—That shown at A includes a half-round ridge tile. The ridge under tiles are nailed to 1¼-in. thick battens which give the required tilt to the tiles to ensure the tails biting the tiles below (although, unlike slating, this is often unnecessary for cambered tiles). The margin between these tiles and the ridge mortar pointing is equal to the gauge of 4-in. This mortar should tone with the colour of the tiles.

A hog-back ridge, closely bedded down, is shown in the detail at B. Here the ridge under tiles are nailed direct to the wood ridge as an alternative to the above. Note that the tiles are shown nailed at every fourth course.

A V-shaped ridge, as shown at F, Fig. 42, may be used. *Lead covered ridges* (see B, J and H, Fig. 73, Vol. I) *should never be employed for plain tiled roofs*. Exposed leadwork clashes with the colour of most tiles. Also, the uniformly straight hard " roof-line " presented by such a ridge is the very opposite to what is required for association with richly textured plain tiles. Little, if any, lead is visible on plain tiled roofs of good-class buildings.

The details at M and N, Fig. 41, show alternative groundwork for tiles. That at M shows boarding, felt and battens. It is not satisfactory, as decay of the battens may result by the lodgment on their upper edges of driven rain and snow. The detail at N shows the employment of two forms of *feather-edged boarding*. One type is rebated (see P) to receive the thin edge of the adjacent board (see N) and the other is of section shown at O. The latter boards are laid to overlap (as indicated at N) by a varying amount according to the gauge. These boards are nailed along both edges to prevent them warping and tilting the tiles. Neither form of this boarding is recommended, for, whilst it has a certain insulating value, felt cannot be conveniently employed, and thus snow and rain may gain access, causing dampness and possible decay of the timber. It is used for cheap speculative or competitive work.

HIP DETAILS (see Fig. 42).—The *granny bonnet hip tile*, shown at B and applied at A, C and D, is generally preferred to the angular type (see E, F, G and H) because of its rounded form and the bold effect which it produces. Its name is expressive of its appearance. As shown, these hip tiles are bonded with the general plain tiling. Each hip tile is well bedded down with haired mortar (1 : 3) on to the back of the tile below and is secured with a sufficiently long nail to the hip rafter. This mortar adds to the attractive appearance of the hip, especially if its colour conforms with the brickwork jointing below, and is given a rough textured surface which is cut back at least ½-in. to produce a shadow. The adjacent side plain tiles are cut and mitred to the sides of the hip tiles, tile-and-a-half tiles being often used for this purpose to ensure that each is secured with two nails. Such cutting is sometimes unnecessary with suitably pitched hip tiles. A side view should show these hip tiles well tilted, namely, the tailed edges should be given an adequate inclination to ensure the top of each curve well above the back of the tile below. Flat bedded tiles (those which fit closely to each other and show only the minimum of bedding material) greatly detract from the appearance.

A suitable finish of a hipped end at the ridge is shown at C. The top pair of bonnet hip tiles is mitred under the ridge, which may be of the hog-back (as shown) or half-round type. The end length at least of the ridge is given a slight tilt upwards and the open end is either filled with mortar cut back at least ½-in. or preferably partly filled in with pieces of plain tile (as shown) or a small section of the upper curved portion of a ridge tile. Care should be taken during fixing to prevent the edges of these insets being stained with the mortar, and the latter should be cut back slightly; this gives a more interesting finish than that provided by a solid-ended ridge tile (compare with F). The slight tilting of the end ridge pieces is also desirable at chimney stack intersections and at verges (see p. 111).

A satisfactory treatment of the lower end of a bonnet hip is shown at A and D. The eaves under tiles are mitred at the intersection (see the plan D) and partly covered with a 2 to 3-in. wide piece of plain tile, called a *tongue*, which is tailed into the mortar. Alternatively, the eaves under tiles may be rounded off at the external angle to the curve of the hip tile. In addition, a relief to the mortar infilling at this lower hip tile is obtained by two plain *tile insets*, described above, or by the insertion of a piece from the upper portion of the tail of a bonnet.

The *cone hip tile* is another type which produces a rounded hip. This tile is 10½-in. long and has a segmentally curved tail, 9-in. wide, which tapers towards its head like the bonnet tile. The plain tiles of each slope at the hip are cut to an open mitre and the cone hip tiles are bedded upon them; they are nailed at their heads to the hip rafter. In appearance this hip is much inferior to the bonnet hip.

*Half-round hip tiles*, similar to those for ridges, are also used (see O and P, Fig. 69, Vol. I). When used for this purpose the effect is distinctly unsatisfactory.

*Purpose-made hip tiles*, known also as *angular hip tiles*, are often adopted. Such a tile is shown at G. An enlarged elevation of the lower portion of a purpose-made hip, slightly sprocketed, is shown at H; a plan and a sketch of a portion of an angular hipped end are shown at E and F. As these hip tiles are bonded in with the general tiling, it is necessary that they conform within certain limits to the dihedral angle of the roof. The method of determining this angle is similar to that for valleys and is briefly explained at M. To ensure the proper bedding of these tiles, and to allow for twisting which may occur during the drying and burning processes of manufacture, the angle of the hip tiles used is generally 5° less than the geometrically determined dihedral angle. Each tile is nailed at its head. The appearance of this form of hip, with its hard angle and neat mechanical line, is unattractive.

*Cut and Mitred Hip Tiles with Lead Soakers*.—Whilst this type is excellent for slates (see G, Q and R, Fig. 69, Vol. I), it is one which is not advocated for tiling, partly because of the difficulty in making such work watertight (especially in exposed positions) and partly on account of the neat and mechanical appearance which it presents.

VALLEY DETAILS.—The *swept* or *circle valley*, illustrated at J and O, Fig. 42,

is undoubtedly the most attractive of the several types adopted, its effective appearance being due to the irregularly shaped units so arranged as to link up the courses of the intersecting slopes by a series of easy curves. When formed by a skilled craftsman, a swept valley is watertight and lead is not required. It is expensive because of the large amount of tile-cutting involved. As much as possible of the dihedral angle is blocked out by the use of a 9 or 11-in. by 1-in. valley board fixed up the valley to the boarding, and the battens are brought over it, as shown. The tiles are cut to the required shape, tile-and-a-half tiles being employed whenever necessary ; in this process the head corners with the nail holes should not be removed in order that the tiles may be adequately nailed. The radii of the curved courses gradually increase from the eaves until a satisfactory curve is obtained at about the fourth or fifth course, after which the radius is more or less constant. Valleys in roofs covered with ordinary slates or stone slates (see Fig. 48) are also swept in good work.

The *laced valley* is another very satisfactory form in the construction of which a valley board is used to pack out the angle (see K and P). No lead is required. Apart from its appearance, a laced valley differs from a swept valley inasmuch as none of the tiles is cut, and the only tile-and-a-half tiles used are those immediately over the valley board ; hence less skill is required in its construction and its cost is much reduced. The battens and tiles are given a gradual sweep upwards so that each pair of courses intersects at a tile-and-a-half tile laid diagonally and alternately right and left handed as shown. As indicated at K, the lower corners of these tile-and-a-half tiles are exposed to form a continuous row of diapers up the valley.

*Purpose-made or angular valley tiles* (see N), like those for hips, are specially shaped to suit the required dihedral angle, the geometrical development of which is explained at M. Allowance is made for any warping that may occur by moulding the tiles at an angle which is approximately 5° greater than that developed. The plan and section at L and Q show a portion of this valley, which is comparatively inexpensive but much less pleasing in appearance, because of its mechanical neatness, than either the swept or laced valleys. Lead is not used. These tiles are often underburnt to prevent twisting, and they thus tend to darken more quickly than the adjacent tiling. The strength of such underburnt tiles is reduced, and they are therefore liable to become damaged by anyone walking on them when carrying out repairs, etc. Leaks may thereby develop and cause dampness.

*Lead valley gutters*, despite their incongruity, are often adopted for plain tiled roofs, chiefly because of their relative cheapness. These include the open and secret valley gutters and those formed with cut and mitred tiles with soakers. They are formed as described for slated roofs (see p. 148, Vol. I). All three are unsuitable because of the uniformity of the hard angles presenting at the intersecting surfaces. Finally, the inappropriate colour and texture of this covering material render the relatively wide open valley gutter type particularly objectionable when associated with plain tile roofs.

## VERTICAL PLAIN TILING

Vertical tiling, also known as *weather tiling* and *tile hanging*, is applied to walls as a protection against rain penetration and for æsthetic reasons. It is especially suited to walls subjected to severe exposure, as it affords a very effective protection, and plain tiles, particularly if they are hand-made and skilfully handled, can produce a pleasing contrast to brickwork when used to cover vertical surfaces.

Details of vertical tiling are illustrated in Fig. 43. The key elevation of a gable wall of a house, finished with facing bricks up to the head of the ground-floor window and plain tiles above, is shown at A. The nails are nailed to either (*a*) battens as for roof tiling, (*b*) coke breeze concrete bricks or slabs built in courses at gauge intervals, (*c*) direct to the mortar joints of the brickwork or (*d*) battens fixed to studs.

(*a*) The detail at Q shows the tiles fixed to 1½-in. by ¾-in. battens which are plugged to the brickwork. It will be observed that, like roof tiling, *there are three thicknesses of tiles at the lap*. The latter is much reduced, a 1½-in. lap being common and all that is necessary. The gauge therefore equals

$$\frac{\text{length of tile} - \text{lap}}{2} = \frac{10\frac{1}{2} - 1\frac{1}{2}\text{-in.}}{2} = 4\frac{1}{2}\text{-in.}$$

Every tile in each course is fixed with 1½-in. copper or composition nails. The sawn laths should be of sound well-seasoned redwood and well creosoted, otherwise when fixed in this position they are liable to decay. Sometimes 2-in. by 1-in. counter-battens are provided ; these are, of course, fixed vertically, being plugged to the wall at 15-in. centres, and the tiling battens are nailed to them.

As in roofing, a double eaves course is provided, the first course consisting of eaves under tiles. That shown at Q is tilted out by the top course of tile creasing. This creasing consists of six courses of ½-in. thick tiles with ⅜-in. bed joints, or three courses of tiles per course of brickwork. The three top courses project with an equal oversail. After bedding, the edges of these tiles should be well cleaned to remove any mortar stains. A part elevation of this finish is shown at P. A more pronounced bell-cast, and one which is usually preferred, is obtained by fixing the tiles in *both* of the courses comprising the double eaves course with the camber uppermost, as shown at R. The latter detail shows a tilting fillet or sprocket and is an alternative to that at Q for providing the required tilt. Another alternative, which serves the same purpose, is a projecting brick course.

(*b*) The section at R shows the tiles nailed to coke breeze concrete bricks or slabs bonded in between alternate heading and stretching brick courses. These so-called *fixing bricks* are made of concrete composed of cement and an aggregate of coke breeze (a product of coke ovens and gas retorts, see p. 29, Vol. II) in the proportion of 1 part cement to 6-10 parts breeze. The size is 9-in. by 4¼ to 5-in. by 1¼ to 1½-in. These bricks may project to afford a ledge for the

nibs, or they may be built flush. Both are shown. Nibless tiles, which can be obtained from some manufacturers (otherwise the nibs are removed), are used if the concrete bricks do not project.

Although coke breeze concrete bricks are often preferred to wood battens on account of the tendency for the latter to decay, the bricks do not afford such a secure nail hold and a preference is therefore given for wood battens for tiling walls in exposed situations. Further, the sulphur present in breeze corrodes the nails, and whilst the rust is claimed to increase their holding power, it is also responsible for their comparatively rapid destruction, especially when in damp localities the corrosion is accelerated.

(*c*) Nailing tiles direct to the mortar joints was formerly a common practice, but it is one which has fallen into disfavour because of the uncertain nail hold provided. As the bed joints of the brickwork must be at the required gauge apart, it is usual for it to consist of bricks-on-edge, the rat-trap bond illustrated at F, Fig. 18, Vol. II, being useful for this purpose, as an approximate gauge of 4½-in. is thereby obtained. The thickness of the bed joints is commonly ½-in. Stout galvanized wrought iron or composition nails, 2-in. long, are used for such direct fixing, copper nails being too soft for this purpose. Tiles without nibs are used, otherwise the length of nail must be increased. The rigidity of the tiles is increased if they are bedded in mortar. The nails are apt to work loose in the mortar, and direct nailing is therefore particularly unsuited for work which is likely to be subjected to the effect of high winds.

(*d*) The fixing of vertical tiling to studs is the traditional method, as such covering was originally associated with timber-framed buildings. A typical wall of such a building consists of a frame having a head, sill and two outer posts with intermediate posts or studs. The spaces between the vertical members may be filled with brickwork, but this is dispensed with when vertical tiling is resorted to. The plain tiles are hung and nailed to 1½-in. by ¾-in. battens fixed horizontally at the gauge apart to the studs. The battens may be of redwood, although oak battens, being less liable to split by the nails, are sometimes used. In order to exclude draughts and to provide adequate insulation, it is necessary for bituminous felt to be nailed to the studs before the battens are fixed. Such construction is very commonly applied between the head of a bay window and the sill of that above it.

In the example shown in Fig. 43, the whole of the tiled area may be studded and constructed in this manner. Alternatively, the brickwork of the gable, covered as shown, may extend to the level of the bedroom ceiling joists, and the upper triangular space completed by 4-in. by 2 or 3-in. studs at 15-in. centres, fixed to a sill bedded on the wall and to the outer pair of spars, battened and tiled.

Because of the protection afforded by the tiles, the normal thickness of external brick walls can be reduced when covered with vertical tiling. Thus, at R the 13½-in. brick wall is reduced to 9-in. at the bedroom floor level. In the alternative detail at Q, the lower portion, not being tile-hung, consists of an 11-in. cavity wall. As there is no need for the cavity to extend beyond the tiling, it is dispensed with as soon as practicable, namely, at the bedroom floor level, and the wall is continued as a 9-in. thick solid structure. Incidentally, this increases slightly the internal dimensions of the upper storey of the house.

ANGLES.—The treatment of external angles is shown at P, where special angle tiles are employed which course in with the adjacent tiling. These are purpose-made right and left-handed for alternate courses, as shown at N. The size varies according to the tile; thus, if a greater bell-cast is required at the eaves, the tilt of the angle tiles would have to be correspondingly increased. In lieu of these special angle tiles, the plain tiles at the angles are cut and mitred; in addition, lead soakers are provided underneath at the intersections for adequate protection. Such construction is similar to that adopted for hips and described on p. 137, Vol. I. Internal angles of wall tiling may also be finished with either purpose-made angle tiles or cut and mitred tiles with lead soakers.

VERGES.—The roofing tiles at a verge should project 2 to 3-in. beyond the face of the wall, the overhang increasing with the height of the building. The thickness of the verge should also vary according to this height. The tiles should be given an upward tilt to prevent the roof water from running down the gable. This also improves the appearance. An undercloak, consisting of one or more courses of projecting plain tiles, butt-jointed, is necessary to provide a satisfactory finish. These tiles are placed transversely and bedded on the wall in cement mortar, the straight ends (and not the cambered edges) being therefore exposed to view. Two verge details are shown at H and J. That at H shows the end pair of spars at a slightly higher level than the rest of the rafters in order to impart the required tilt. The battens are brought over the single tile undercloak to within 1-in. from the face of the wall. The space between the undercloak and the tiles above is filled in and pointed with cement mortar either flush or cut back ½-in.; the tiles are also pointed (see H, K and O). The tile edges should be free from mortar stains. The end roofing tiles in alternate courses must be tile-and-a-half tiles and *not half tiles*, as the latter cannot be securely fixed. To prevent the warping of the comparatively large tile-and-a-half tiles, some manufacturers purposely underburn them. Such should not be used, because of their colour differing from the rest of the tiles (which difference is increased on exposure) and because of their liability to disintegration. The end rafters are shown in the detail at H to be approximately 4½-in. from the outer face of the wall in order to reduce the projection of the battens, although the usual practice is to fix the rafters close to the inside face as shown at J.

An alternative method of obtaining the necessary tilt is to arrange the end pair of rafters level with the top of the wall; the undercloak tiles are then bedded and the battens are bent over them.

The detail at J, showing a cavity wall untiled, is suitable when only a slight tilt, provided by the mortar bedding, is required. The thickness of the verge is increased if a cement fillet between the wall and undercloak (shown by a short

broken line) is formed. A double tile undercloak, which gives a bold effect, is shown at S.

Two methods of treating the vertical tiles at the verge intersection are shown at O, K and S. That at O and K, known as the *Winchester cut* method, gives much the better appearance, the fan-shaped effect being produced by cutting at each end of each course the end tile and adjacent tile to the required splay and tilting the end tile. This tilt should not be excessive in order to ensure that one nail hole and nib of the adjacent splayed tile are preserved. The intersection between the vertical tiling and the undercloak is pointed in cement, as shown. The alternative finish at S shows that only each end tile in each course is splay cut, and this method is therefore cheaper than that of the Winchester cut, which necessitates the cutting of two tiles at each end. This second method is only possible if, as shown, a tile-and-a-half tile is used at the end and a nib and hole made available. The intersection between the undercloak and the vertical tiling is neatly pointed with cement mortar.

Eaves.—The finish of the vertical tiling at the eaves of the roof depends upon the projection. The detail at O shows one method in which a hard stone corbel is used to support the brickwork. It will be observed that the intersection between the bottom tilted tile and the angle tile coincides with the bottom of the corbel.

If the gable is not hung with tiles, an interesting feature is provided by tile corbels, such as is shown at T.

Ridge.—The detail at K shows the appearance of the apex of the gable when the two top tilted tiles are mitred under a half-round ridge tile with tile insets.

Window Openings.—Details at the head and sill of the upper window are provided at L and M. The former shows a single projecting tile soffit at the head of the window and a proper double course of vertical tiling. The soffit may consist of two courses of tiles, projecting as shown at Q. Alternatively, like that at R, a tilting fillet or sprocket may be used and a pronounced bell-cast imparted. The edges of the tiles at the reveals must be well bedded and pointed with cement mortar. Tile-and-a-half tiles, and not half tiles, should be used at alternate courses at the reveals, especially in exposed positions.

The detail at M shows a sound and effective method which ensures watertight construction at the sill of the window. The desirability for not exposing lead to view when associated with plain tiling is referred to on p. 108. Hence, in this detail, a *secret apron* has been employed. The apron, hooked over the edge of the water bar before the window is fixed, is dressed over the tile course nailed to the battens immediately below the sill, as shown. If a water bar is not provided the upper edge of the apron should be tucked in the groove of the sill. A course of short tiles is then well bedded in cement mortar or haired lime mortar spread on the lead apron. The heads of the tiles are inserted in the groove provided in the sill, and their tails should line with the general tiling. The lead apron should be well scored (scratched) to afford a better key for the mortar.

A cheaper method is to dress the lead over the top course of the tiles, and it is therefore exposed to view, as in slating (see A, B and E, Fig. 73, Vol. I).

Vertical Slating.—Slates are also used to cover walls, especially of buildings where severe weather conditions are likely to be met. Whilst vertical slating affords an excellent protection, its appearance is less pleasing than that of vertical tiling, especially if large, thin, smooth textured slates are employed. Like plain tiles, slates may be fixed to battens, concrete bricks, direct to mortar joints or to studs. The slates at external and internal vertical angles are mitred, and soakers are provided as explained on p. 111.

## PANTILING

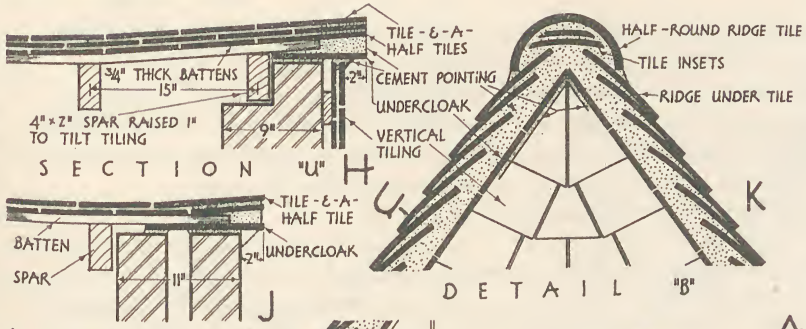
Manufacture of Clay and Shale Pantiles.—The preparation of the clay or shale, and the drying and burning processes are as described for plain tiling (pp. 104 and 105). Pantiles are from 13 to 14-in. long, 9 to 10-in. wide and $\frac{1}{2}$, $\frac{5}{8}$ and $\frac{3}{4}$-in. thick (see A, Fig. 44). They are not cambered but are flat from head to tail, and they are curved transversely to a flat-wave or S-section. One nib is provided at the head on the underside of the trough of the wave, a nail hole is formed below the nib, and two of the opposite diagonal corners are splayed or rounded, as shown at A and B, Fig. 44. Pantiles are hand and machine moulded.

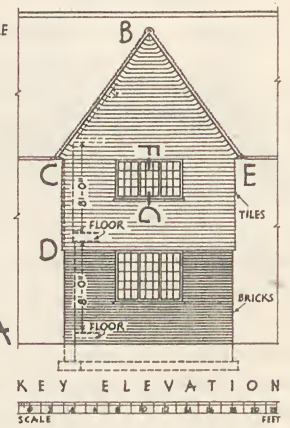
The wood mould used in hand-moulding is similar to that described for bricks (p. 4, Vol. II), being rectangular in shape and with the two opposite diagonal corners blocked out with triangular pieces ; the shaping of the slab is performed as explained on p. 104 ; the stockboard (see p. 4, Vol. II) has a small nib-shaped depression at one end, and the nib is accordingly made at this operation. The slab is removed and placed on a *washing-off frame*, which is simply a mould having its upper surface curved to an S-shape. The moulder with wet hands then presses the slab to the curved form. After being partially dried, the curved slab may be taken to the *thwacking frame* (a wood mould with an S-curved top) and beaten with a *thwacker* (a wood blade resembling a small cricket bat) to consolidate the clay and correct any twisting which may have developed. The edges are finally trimmed with a knife and the slab is removed to dry after it has been holed as described on p. 104. Because of the additional cost which it entails, this thwacking operation is now usually omitted, and the toughness and durability of the tiles are thereby affected adversely.

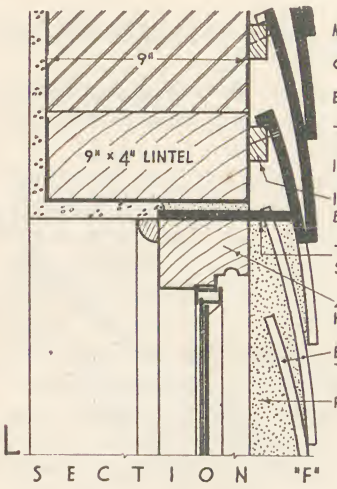
Pantiles are machine-made by the wire-cut process, the band of clay extruded through a mouthpiece shaped to the required cross-section being cut to length, nibbed and holed as described on pp. 104 and 105.

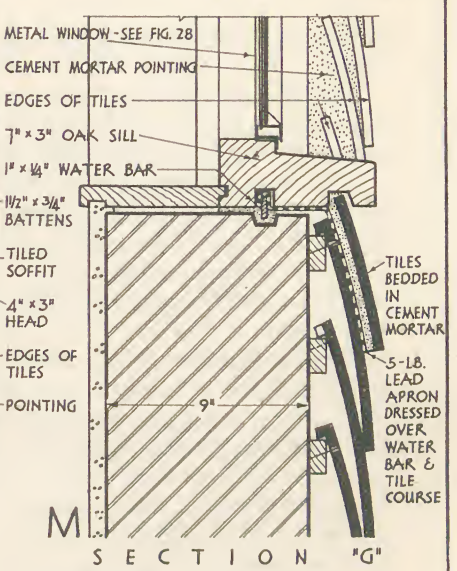
Details.—There are several differences between plain tiling and pantiling. Whereas plain tiles are laid with butt side joints with three thicknesses at the lap and two thicknesses between laps, pantiles are laid with *overlapping side joints* with *two* thicknesses only at the head joints and a single thickness at the unlapped portions. Further, whilst plain tiles have a bonded appearance, pantiles are unbonded, having continuous side joints from eaves to ridge. Pantiles are thus

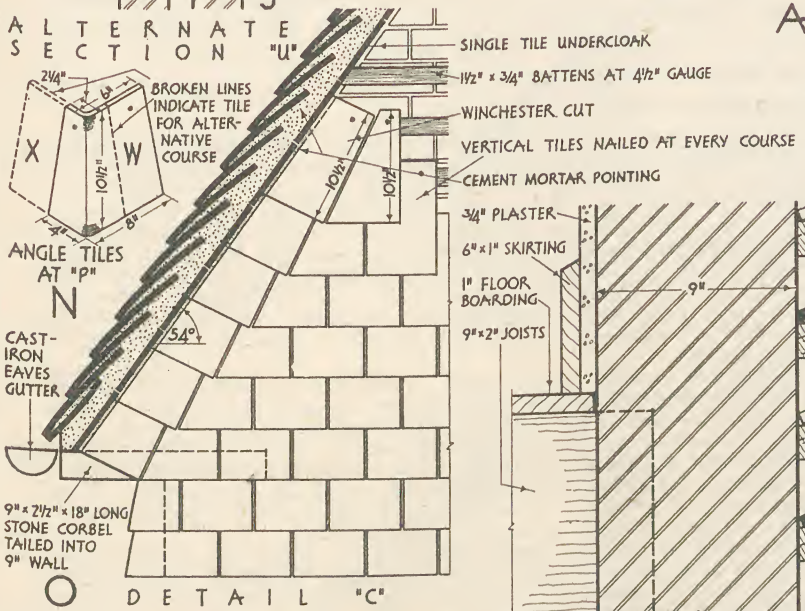
# VERTICAL PLAIN TILING

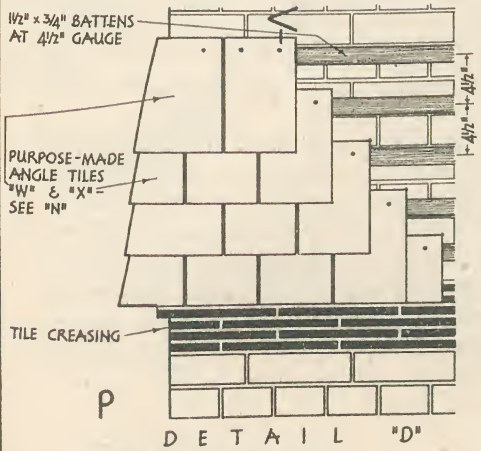


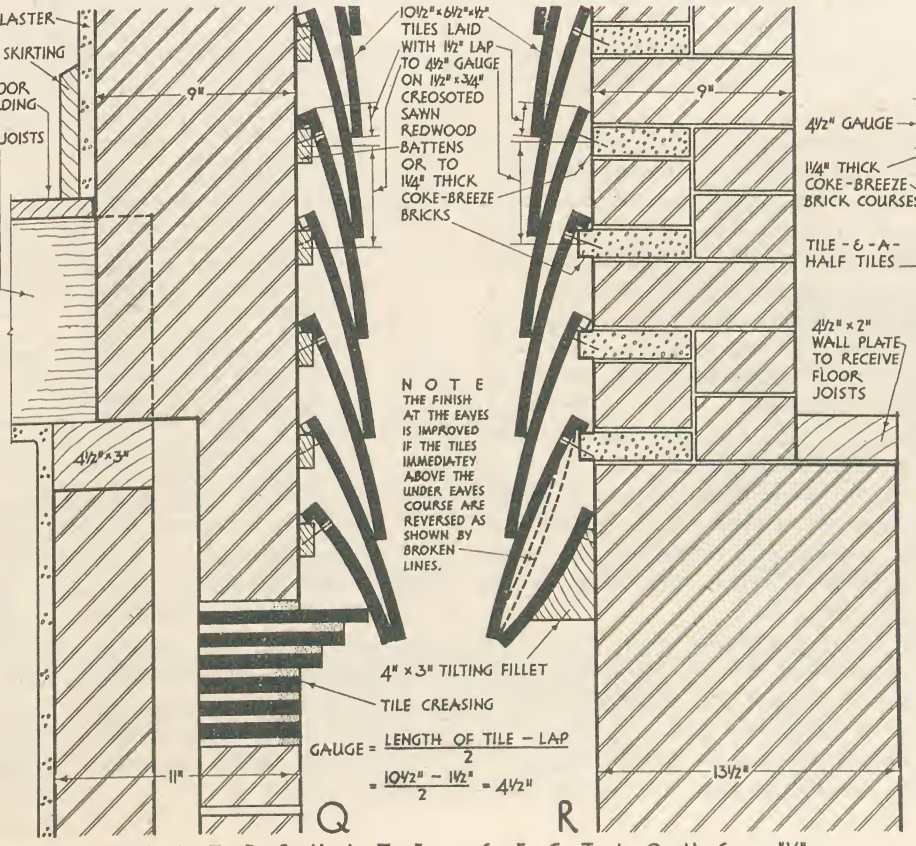



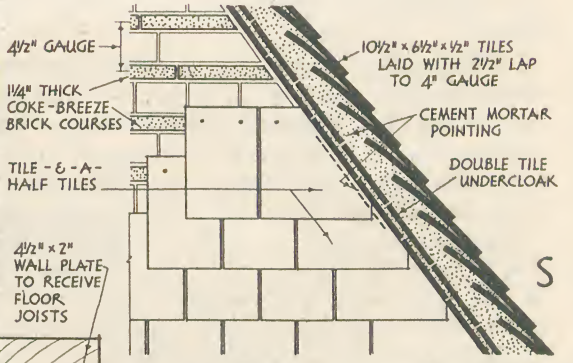





9"
10½" x 6½" x ½" TILES LAID WITH 1½" LAP TO 4½" GAUGE ON 1½" x ¾" CREOSOTED SAWN REDWOOD BATTENS OR TO 1¼" THICK COKE-BREEZE BRICKS
9"
4½" x 3"
NOTE
THE FINISH AT THE EAVES IS IMPROVED IF THE TILES IMMEDIATEY ABOVE THE UNDER EAVES COURSE ARE REVERSED AS SHOWN BY BROKEN LINES.
4" x 3" TILTING FILLET
TILE CREASING
GAUGE = LENGTH OF TILE − LAP / 2
= 10½" − 1½" / 2 = 4½"
11"
13½"
Q
R
ALTERNATE SECTIONS "V"
SCALE FOR L,M,Q & R
INCHES


4½" GAUGE
1¼" THICK COKE-BREEZE BRICK COURSES
TILE-&-A-HALF TILES
4½" x 2" WALL PLATE TO RECEIVE FLOOR JOISTS
10½" x 6½" x ½" TILES LAID WITH 2½" LAP TO 4" GAUGE
CEMENT MORTAR POINTING
DOUBLE TILE UNDERCLOAK
S
ALTERNATE FINISH AT VERGE

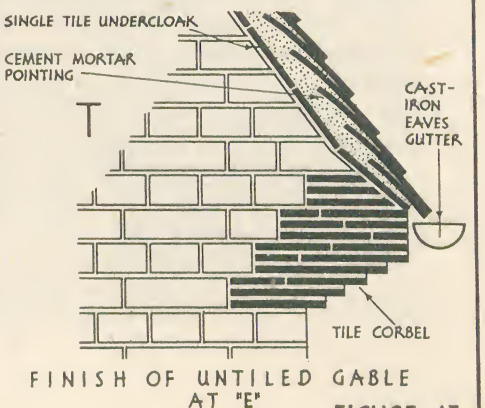



FIGURE 43

described as being *single-lapped*, as distinct from plain tiles which are *double-lapped*.

Pantiling is detailed in Figs. 44 and 45. A cross-section through two adjacent pantiles at C, Fig. 44, shows the side lap which varies from 1½ to 2-in. A plan, to a reduced scale, of these tiles is shown at D.

The head or longitudinal lap varies from 3 to 4-in., according to the pitch of the roof and the degree of exposure. The gauge equals the length of tile – lap ; thus, that of 14-in. long pantiles, having a 3-in. lap, equals 14-in. – 3-in. = 11-in. The pitch varies from 30° to 47½° ; if the latter is exceeded there is a tendency in a storm for the water streaming down the shallow channels to overshoot the eaves gutter.

The comparative gauges being 4-in. for plain tiles (see p. 106) and 11-in. for pantiles, the covering capacity of the latter is greatly in excess of that of plain tiles. Thus, the approximate number of pantiles required per square (100-sq. ft.) is 170, whereas approximately 550 plain tiles are required to cover the same area. The average weight of pantiles, when fixed, is about 7½-lb. per sq. ft., and is therefore much lighter than a plain tile covering which may reach 14½-lb. per sq. ft. Hence smaller roof timbers may be used for pantiles (or the distance between purlins may be increased) than those required for plain tiling, and therefore the employment of pantiling results in an economy in roof timber.

The two diagonally opposite corners or *shoulders* are splayed off to the depth of the lap, as shown at D, Fig. 44, to permit of a reasonably close fit being maintained between the tiles ; otherwise four thicknesses of tile would occur at the corners, resulting in open joints due to the tilting or overriding of the tiles. The joining of the bottom left-hand bottom corner of a tile with the top right-hand corner of the tile below and to the left is called *shouldering* and is illustrated at H.

Pantiles are nailed as required and as specified for plain tiling (see p. 106). The greater the exposure, the more frequent the nailing. The groundwork for both types of tile is also similar ; 1½-in. by ¾-in. tiling battens are commonly employed, although 2-in. by 1-in. battens are also used.

Eaves Details.—Two details are shown at J and L, Fig. 44. That at J shows a simple closed eaves. Untearable felt is nailed to the backs of the spars and 1½-in. by ¾-in. tiling battens are fixed at the gauge apart—11-in. Although an under-eaves course is not absolutely necessary, a more satisfactory finish is obtained if one is provided. That shown consists of a course of eaves under tiles ; a course of ordinary plain tiles is sometimes adopted. The bottom course of pantiles is bedded on mortar on the plain tiles.

The alternative eaves detail at L shows the external leaf of the cavity wall finished with six projecting courses of uncambered plain tiles. The groundwork conforms to the best practice, namely, tongued and grooved boarding covered with felt, counter-battens at 15 to 16-in. centres and tiling battens at gauge centres. The spars are slightly sprocketed and the bottom course of pantiles is bedded on a course of nibless eaves under tiles. A part elevation of this eaves is shown at K. The eaves gutter has been omitted. Small plain tile insets (see p. 108) provide a relief to the mortar bedding.

Occasionally three or four courses of plain tiling are provided at the gauge (4-in.) apart in the usual manner at the eaves of a pantiled roof. This treatment is traditional, and its object is to distribute the flow of water from the channels of the pantiles above and so prevent it from overshooting the gutter.

An alternative eaves detail is shown in Fig. 18.

Ridge Details.—Two are shown at F, Fig. 44, the groundwork on the left being similar to that at J, and the timbering and felting on the right are as shown at L. *Galleting* is shown in both, namely, two small pieces of plain tile are bedded in each channel and finished level with the top of the corrugations (see also G, Fig. 44, and E, Fig. 45). Besides providing an interesting feature and reducing the amount of bedding mortar, this packing up to the ridge ensures a level bed throughout for the latter.

Three traditional methods for ensuring a " drop-dry " roof were : (1) Pointing the tail and side joints, (2) lathing and bedding under the side joints and (3) reeding and bedding. None of the three methods is now recommended. Regarding :

1. Whilst the pointing of the joints can be done effectively, as the mortar is applied from the outside, there is evidence to show that tiles on old roofs which have been treated in this manner were defective where they contacted the mortar, although the remainder of each tile may have been perfectly sound. This decay was probably due to the slow drying out of absorbed water or that driven through cracks, etc., in the pointing. Frost action would accelerate the decay. In course of time the pointing becomes defective and re-pointing is necessary. Pointing detracts from the appearance of a roof.

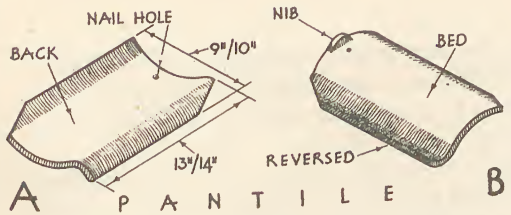
2. Lathing and bedding the side joints, known as *strip lathing*, is effected by nailing two or three plasterers' laths (⅞-in. by ¼-in. by 2½ to 4½-ft. long) at " finger spacing " (⅜-in. apart) to the tiling battens at 8-in. centres (or side joints apart) and running from eaves to ridge. Lime mortar is then spread on the laths as the tiles are fixed and bedded on the fillets at the side joints. A fillet and laths are indicated by broken lines at L, Fig. 45. Whilst this gives a firm bedding to the tiles, the application of this method is deprecated because of the tendency for the tiles to decay where they contact the mortar and for this decay to spread to the roof timbers.

3. This somewhat primitive method consisted of packing reeds (marsh grasses) over the spars between the tiling battens and parallel to the latter. The reeds were kept in place by short laths placed over them at 2-ft. intervals with their ends tucked under the tiling battens. The tiles were then bedded on mortar fillets at their side joints. Any water driven in was soaked up by the reeds, and the latter was effective in preventing the pantiles covering roofs of barns, sheds, etc., from being lifted up and dislodged by gusts of wind.

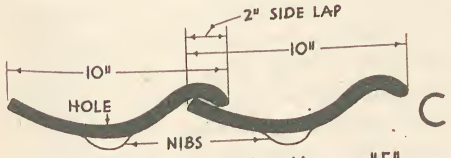
Now that roofing felt is available, it is difficult to justify the continuance of any of the above three methods, even if their initial cost is less.

Verge Details (see G and H, Fig. 45).—That at H shows the usual treatment of a right-hand verge when the groundwork consists of boarding, felt, counter-battens and tiling battens, an undercloak consisting of three courses of plain or flat tiles providing a suitable finish to the verge pantiles which are bedded on and pointed with cement mortar or compo consisting of 1 part cement, 1 part lime and 4 parts sand. The undercloak projects 2 to 3-in., depending upon the height of the building. The width of the upper course of plain tiles is reduced, as shown, to permit of the hanging and nailing of the verge tiles to the tiling battens.

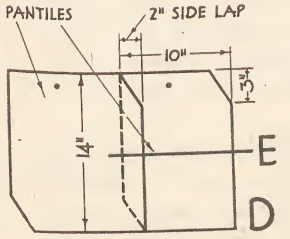
# PANTILING




A PANTILE B

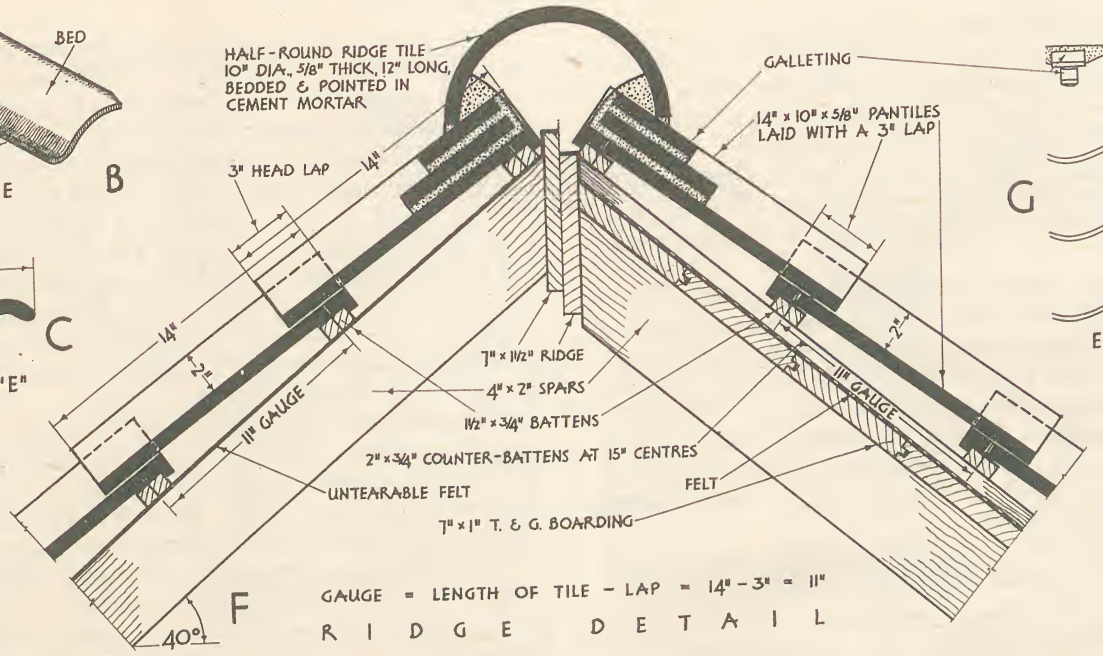



SECTION "E" C




E D

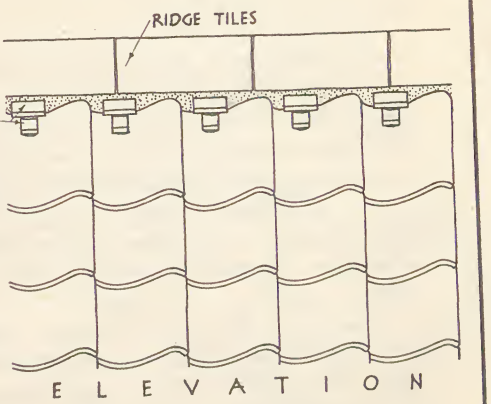
PLAN SHOWING SIDE LAP


HALF-ROUND RIDGE TILE 10" DIA., 5/8" THICK, 12" LONG, BEDDED & POINTED IN CEMENT MORTAR
GALLETING
14" x 10" x 5/8" PANTILES LAID WITH A 3" LAP
3" HEAD LAP
14"
2"
11" GAUGE
7" x 1½" RIDGE
4" x 2" SPARS
1½" x ¾" BATTENS
2" x ¾" COUNTER-BATTENS AT 15" CENTRES
UNTEARABLE FELT
FELT
7" x 1" T. & G. BOARDING
40°

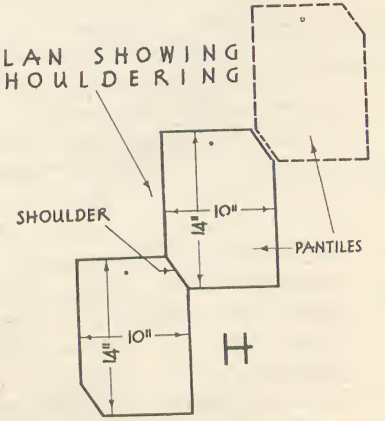
F

GAUGE = LENGTH OF TILE − LAP = 14" − 3" = 11"

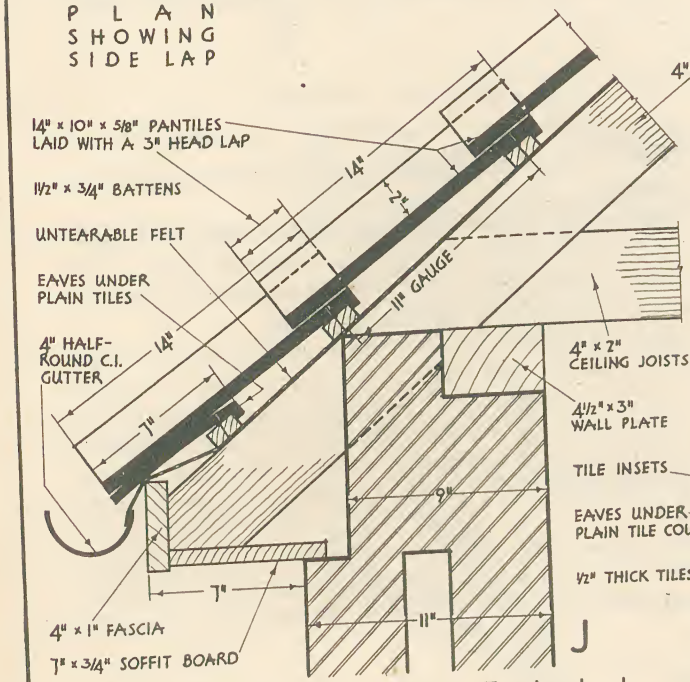
RIDGE DETAIL



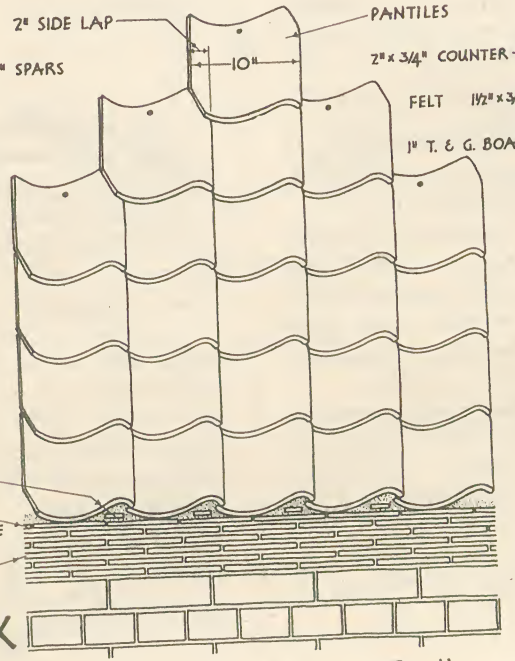

G ELEVATION



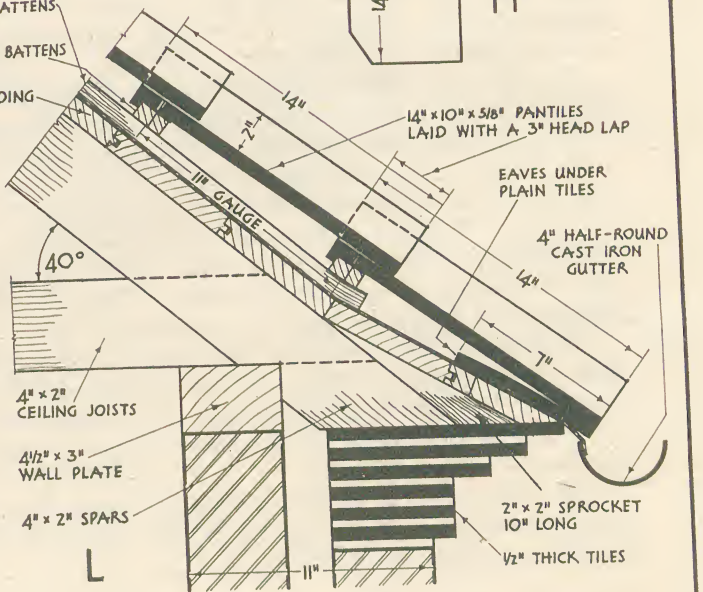

PLAN SHOWING SHOULDERING H



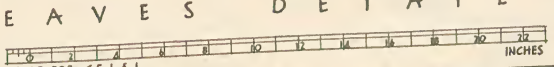

J EAVES DETAIL




K ELEVATION




L EAVES DETAIL




SCALE FOR C,F,J & L

SCALE FOR A,B,D,G,H & K

FIGURE 44

The detail at G shows a left-handed verge. The narrow curved purpose-made verge tile shown is necessary at each course to balance the roof and present the same appearance at both verges. Alternatively, purpose-made double " roll " verge tiles are used ; as these can be hung on and nailed to the tiling battens, in addition to being bedded, they are preferred to that shown at G where the narrow verge tiles are bedded only. One of the two verges at a gable will be as shown at H, and the other on the opposite slope will be finished with purpose-made tiles ; the thickness of the pointing should, of course, be the same at both verges.

ABUTMENT DETAILS.—Formerly, when purpose-made verge pantiles were not available (and therefore symmetrical treatment at the verges was not possible unless the verge tiles on one slope at each gable were cut and the rolls removed), it was a common practice to finish gable walls with low thin parapets as shown at D, Fig. 45. A brick-on-edge coping, surmounting a double plain tile creasing which oversailed a cement fillet splayed down to the pantiles, was provided. Sometimes the parapet was only 4½-in. thick. Whilst this provided a pleasing appearance the construction was not sound, as water was liable to penetrate the wall, as indicated by the thick broken arrows.

Sounder construction, presenting the same external appearance, is shown at B, where the cavity of the gable wall extends to the tile creasing. An isometric sketch of this detail is shown at E. This also illustrates a satisfactory treatment of the roof at a chimney stack. Galleting is shown at the ridge and at the three channels of the pantiles intercepted by the stack. Cut plain tiles are bedded on the latter galleting and continued up the slope where the upper end is covered by the ridge tile. A neat mortar fillet is formed over these cut tiles and at the ridge intersection. This sketch also shows the groundwork described on p. 114 in connection with the detail at H.

An alternative detail, showing a cavity wall finished with a stone coping, is given at A. This also shows a cement fillet, neatly splayed or rounded off, covering the intersection between the tiles (and the ridge) and the wall.

In the above abutment details, cement fillets have been shown at the intersections. It is advisable to add a 5 per cent. waterproofer (see p. 27, Vol. II) to the mortar. Whilst these fillets present a satisfactory appearance when associated with pantiles, mortar is a very unreliable material for this purpose, as the fillets have a tendency to crack and fall away. They therefore require occasional attention, and the making good of any defects, if water is to be excluded.

Undoubtedly the provision of lead flashings at abutments, in lieu of mortar fillets, is the soundest practice. But, as already pointed out, leadwork does not harmonize with tiles in general because of its colour and texture. The section at C shows, as an alternative to the cement fillet at A, a lead apron flashing which is dressed over the tiles.

HIP DETAILS.—The cutting of pantiles is both difficult and expensive, and therefore intersections resulting from hips, valleys, dormers, etc., should be avoided or reduced to a minimum.

The detail at K, Fig. 45, shows an elevation of a portion of the roof illustrated at K and L, Fig. 44. The hip is of half-round tiles bedded on the pantiles on adjacent slopes which have been cut to form an open mitre up the line of the hip. Conical hip tiles are also employed.

VALLEY DETAILS.—A typical valley is shown at J, Fig. 45. The lead forming the gutter is dressed over the valley board and up each slope, where it is either turned over at the edge, as shown on the left, or dressed over a tilting fillet as indicated on the right (see p. 148, Vol. I). A layer of flat plain tiles is laid up the slope at each side, butt-jointed in mortar at their ends, and the cut pantiles are bedded on them. Pieces of tile may be embedded in this bedding to form tile insets. The roofing felt is brought over the plain tiles as shown. The somewhat unusual appearance of the pantiles is due to the vertical section being taken normal to the line of the valley.

Purpose-made valley tiles, slightly curved or V-shaped in cross-section, are now available. Lead is not required when these are employed, the roofing felt being continued over the valley board, and the valley tiles, laid with a 3-in. lap, are nailed to the board. The cut pantiles are bedded on the sides of the valley tiles. A very satisfactory appearance results.

Pantiles, being comparatively big units, are best suited for covering large roofs requiring a bold and simple treatment. Those of best quality, especially if hand-made, are used in first-class work, whilst pantiles of inferior quality are suitable for roofs of farm and similar buildings where an inexpensive covering is desired.

## ITALIAN OR ROMAN TILING

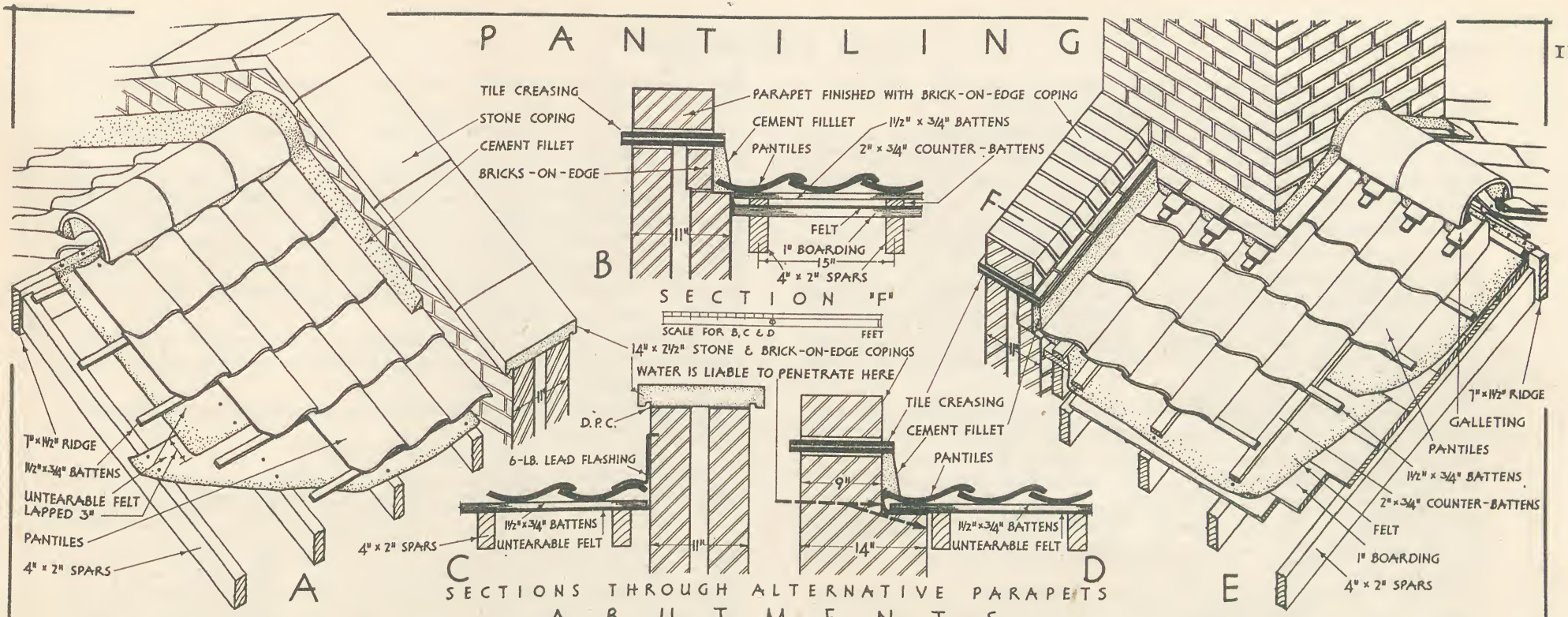
This is illustrated in Fig. 46.

The various forms of this class of tiling include (*a*) Old Roman, (*b*) Single Roman and (*c*) Double Roman.

(*a*) OLD ROMAN TILING.—This is also known as *Basilican tiling*, and, more commonly, as *Italian tiling*. It is another example of single-lap tiling. The tiles, which are hand-made, consist of flat *under* tiles (abbreviated to *unders*), which alternate with convex curved *over* or *top* tiles (or *overs*).

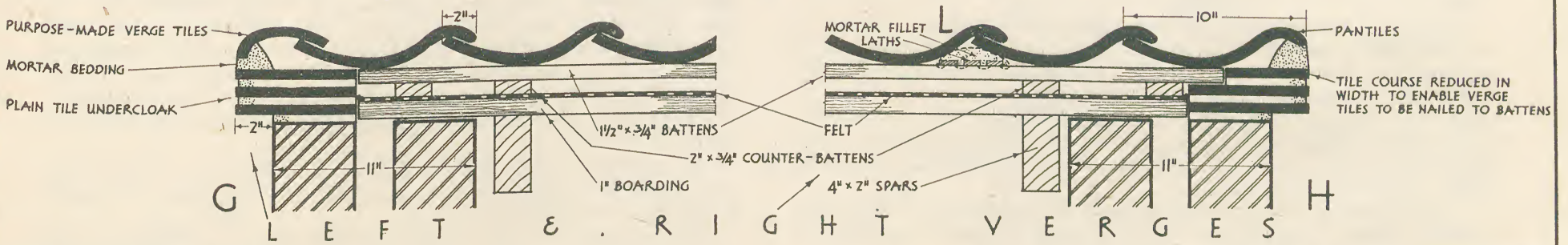
An under is shown at B. It is flat, tapered, with upturned edges or flanges at the sides, and is provided with two nail holes. Its length is 15½-in., its width varies from 9¼ to 9½-in. at the tail and 10¾ to 11-in. at the head, and it is ½ to ⅝-in. thick. Some are provided with two transverse grooves near the head ; these capillary grooves are effective in minimizing updrift. The end views of the head and tail show that the flanges are tapered, with a slight increase in depth towards the head.

An over (see A) is also 15½-in. long, tapered on plan, half-round at the tail, slightly less in height at the head, and is provided with one nail hole. As shown, the tile may be slightly shouldered to allow it to clear the unders in the course above at the head lap.

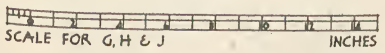


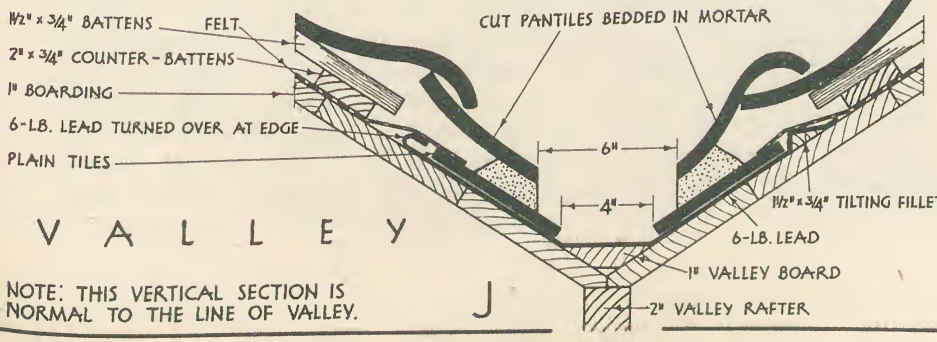

SECTIONS THROUGH ALTERNATIVE PARAPETS

## ABUTMENTS



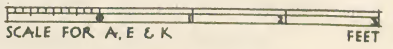

LEFT & RIGHT VERGES

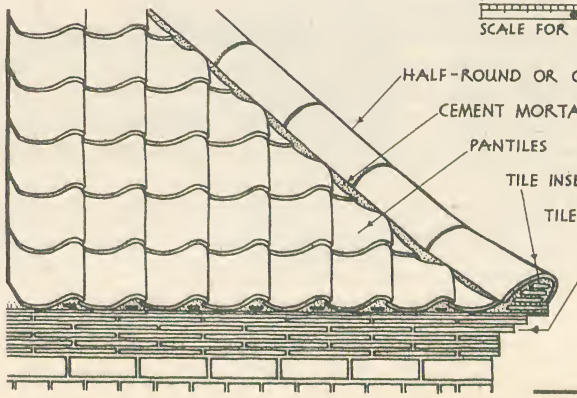



VALLEY

NOTE: THIS VERTICAL SECTION IS NORMAL TO THE LINE OF VALLEY.




HIP

FIGURE 45

The head lap varies from 2½ to 3-in., depending upon the pitch (see L). The minimum pitch is 35°. The side lap is 2-in. (see G).

The groundwork may consist of 2-in. by 1-in. battens, fixed at the gauge apart to the spars which have been previously covered with untearable felt. Alternatively, 1-in. boarding, covered with felt, may be used. The gauge equals length of tile − lap = 15½-in. − 3 (or 2½)-in. = 12½ or 13-in. In addition, a 3-in. by ⅞-in. vertical batten is fixed between each pair of unders at 11⅝-in. centres (see G), otherwise very long nails would be required to secure the overs. A vertical batten is fixed immediately a row of unders is completed. The unders are fixed to the battens or boarding with 1½-in. copper nails, and 3-in. nails are used to fix the overs to the vertical battens. A true plan of a portion of two courses, showing the setting out, is given at H, a part elevation is shown at K and a section at an eaves is shown at L. The detail at T (see next column) may be adopted also.

As shown at K and L, it is usual to provide a course of plain eaves under tiles at the eaves. Besides presenting a satisfactory finish, this affords a suitable bed for the unders and the mortar which is used to fill in the hollows of the eaves over tiles. The mortar should be cut back for about 1-in. to give a shadow.

The finish at the ridge is similar to that shown for pantiling, half-round tiles and galleting being usually employed. The hip, valley and verge details are also similar. A balanced effect at the verges is obtained by using overs upon plain tile undercloaks.

These tiles, which are highly textured and obtainable in several colours, present a bold and distinctive appearance, which is especially suited for large roofs.

(*b*) Single Roman Tiling.—A single Roman tile is shown at D, Fig. 46. It is rectangular on plan and is 13½-in. long by 10-in. wide by ½-in. thick. A flat portion, 6¾-in. wide at the head, tapering to 6-in. at the tail, has one edge slightly upturned and its opposite side is in the form of a fairly bold slightly tapered roll. It is thus a combined under and over Italian tile described on p. 116. Like a pantile the hand-made tile has its two opposite diagonal corners splayed. Some are provided with two holes on the flat near the head, whilst others are without holes. Each has a continuous nib.

The head lap is 2½ to 3-in. and, as shown at C, the side lap is 2-in. Being another example of single-lapped tiling, the gauge is 10½-in. when the head lap is 3-in (see M). The minimum pitch is 35°.

A detail showing a suitable finish at the eaves is given at M. Here the groundwork is simply battens nailed to the spars which are covered with untearable felt. Other groundwork may consist of tiling battens fixed to felt-covered boarding, or tiling battens nailed to counter-battens nailed to felt-covered boarding. Vertical battens are not required, as the tiles, when nailed, are not secured at the 2-in. high rolls.

The finish at the ridge, hips, valleys, abutments and verges are as described above. In order to present a balanced appearance at verges, purpose-made single Roman tiles are available, each having a double roll, for the left-hand verges.

In appearance, a roof covered with these tiles is similar to, but less vigorous than, an Italian tiled roof.

(*c*) Double Roman Tiling.—These tiles, shown at E, are 15 to 16½-in. long by 11 to 13½-in. wide. Each has two rolls, hence the name. The left-hand tail corner is splayed and a portion of the middle roll is shouldered at the head, as shown. As indicated at E, these tiles are laid with " break joints," and therefore special half tiles are required at alternate courses at verges to complete the bond. Purpose-made left-hand verge tiles, provided with three rolls, are available to give a symmetrical roof.

The head lap is usually 3-in. and, as shown at F, the side lap is at least 1½-in. The minimum pitch is 35°. Nailing is not required, as the tiling is tightly fitting and cannot be lifted by the wind.

The groundwork and the finishes at the ridge, eaves, hips, etc., are as described in the preceding column.

## SPANISH TILING

Spanish or *Sicilian tiling* is very similar to Italian tiling, the only difference being that the under tiles are not flat like the Italian type but are concave-shaped.

An over is shown at N, Fig. 46, and an under at O. The length of each is 14-in. The overs taper down from the tail to the head and the unders from the head to the tail (see the dimensioned end views). The width of each is not standard, there being a slight variation in some of the tiles produced. They are hand-made. Like Italian tiles, each Spanish under is secured by two copper nails and each over by one nail. Vertical battens must be provided to take the 3-in. nails securing the overs; the unders are also skew nailed (1¾-in. nails) to these 3-in. by 2-in. battens (see S and the heads at N and O). The spacing of the vertical battens for tiles of the dimensions indicated is 10½-in. centres (see P and S). As shown, the top edges of these battens are slightly chamfered to provide the necessary clearance for the unders; sometimes these battens are tapered to 1-in. at the top.

The minimum pitch is 35°, and the head lap varies from 2½ to 3-in. The gauge is therefore either 11½-in. (14 − 2½-in.) or 11-in. (14 − 3-in.). The forms of groundwork are as for Italian tiling.

The bold character of the appearance may be gauged by the part elevation at Q. This appearance is sometimes modified by the use of shorter overs at the eaves (and correspondingly longer ones at the ridge) and thus their tails are lower than those of the unders except at the eaves line.

The treatment at the eaves may be as shown for Italian tiling at L and M. Alternatively, a very attractive appearance is obtained when, as shown at T, the tiles are brought over the outer edge of the eaves gutter. In this detail the bottom course of plain eaves under tiles and the bottom course of unders are purpose-made and provided with holes (see also Q) to allow the water passing down the channels to enter the gutter. The cast iron gutter, which is given

# TILING

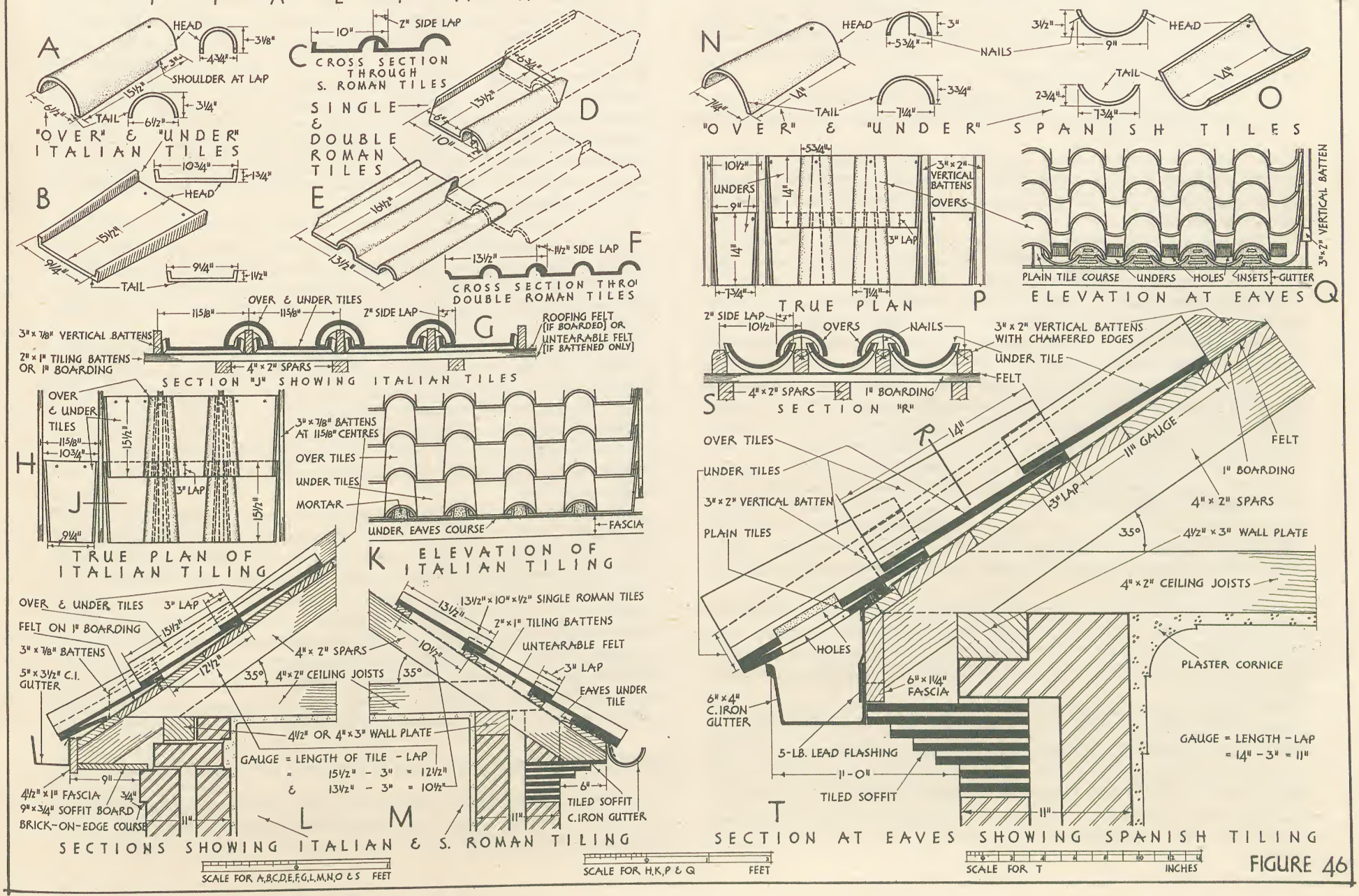



FIGURE 46

a minimum fall, must be well screwed to the fascia. The double top tile course forming part of the soffit is provided to ensure that the wood fascia will not be exposed to view at the highest part of the gutter. A lead flashing, as shown, ensures watertight construction, and the roofing felt is brought over its upper edge. The hollows of the over tiles at the eaves are filled with mortar, and tile insets, shown at Q, add to the appearance. The lower ends of the vertical battens are cut short (see T and Q) to permit of this.

NOTE.—*The space between the head of the bottom over tile and the tail of that above it is exaggerated and is due to the clearance at the laps of the unders which has been shown purposely to make the detail clear.*

The ridge is usually finished with half-round or segmental ridge tiles. Conical or tapered hip tiles which course in with the Spanish tiles provide a suitable finish at the hips. Verges are treated as before described, as are also valleys and abutments.

There are several forms of tiles manufactured to resemble Spanish tiles. Thus, the overs are sometimes hog-back in shape, and in another type both unders and overs are much flatter than the traditional form.

INTERLOCKING TILES.—A number of tiles are now made which have patent locking devices, the object of which is to prevent their dislodgment even in the most exposed positions. Some of these do not require nailing, whilst others are secured to battens by means of wire. Thus, for example, one device consists of two lugs formed on the underside at the tail of an Italian over, which closely engage the shoulders at the head of the over which it overlaps. In the " wired " variety, which has usually a head and side locking device, a piece of wire is passed through a hole formed in a nib and twisted round the batten.

Most tiles of the interlocked type are machine-made. Some of these, of continental origin, have stamped on them a central ornament in relief, such as a rib or diaper. Because of their initial cheapness, and also owing to the available local materials failing to meet the large demand which followed the Great War, large numbers of these foreign tiles were used in this country. Many were underburnt and so lacking in durability that they had to be replaced within a very short period.

CONCRETE TILES.—Within recent years there has been an increasing demand for roofing tiles made of concrete or cement mortar. Plain tiles, pantiles, interlocking tiles, and ridge, hip and valley tiles are made of this material. Cement, sand or crushed stone, pigments and an accelerator are materials employed in their manufacture.

The cement used is usually ordinary Portland cement. The aggregate must be clean, well graded and must pass a $\frac{1}{8}$-in. sieve. The pigments vary according to the colour desired. Thus, a black is produced by carbon black pigment, blue by ultramarine pigment, brown by burnt umber pigment, yellow by yellow ochre, green by chromium oxide and a red colour is effected by the use of red oxide pigment. An accelerator is introduced to expedite the rate of hardening, and that used is calcium chloride.

Concrete tiles are produced in machines which are either of the hand-operated or the automatic type. Thus, concrete plain tiles, which are cambered, each having two nibs or a continuous nib and of the same size as clay plain tiles, are made in a hand-operated machine in the following manner: The cement, aggregate, accelerator and water are thoroughly incorporated in a batch mixer (see p. 34, Vol. II). An oiled pallet is placed in the cast-iron moulding box of the machine which is then filled with concrete. After being consolidated the surface of the concrete is levelled or struck off and the pigment, mixed with cement and sand, is sprinkled over it from a sieve and trowelled in. In some machines the area of the pallet and box is twice that of the tile, and after the last operation, a hinged metal frame is swung down to divide the concrete slab into two and form the nail holes. The pallet with the two nibbed and cambered tiles is raised by depressing a treadle.

In an automatic machine the above operations are effected as the pallets on a track are automatically moved and brought in turn under separate parts of the machine. Thus, in sequence, the pallets are sprayed with oil, fed with the mortar mix, consolidated, surface smoothed off, cut into units by a rotating knife, surface colour applied and rolled in, nail holes formed and the edges finally trimmed.

After moulding, the tiles (with their pallets) are carefully stacked horizontally on racks and taken to the curing chamber, in which the air is conditioned to the required temperature and humidity, and left for twenty-four to forty-eight hours, according to the amount of accelerator added to the mix. The tiles are de-palleted, dipped in a tank containing sulphate of iron solution (which improves the colour and removes any white film formed whilst in the chamber), and finally removed to an open shed or yard where they are stacked to complete the hardening process.

The quality of concrete tiles is covered by the British Standard Specifications for " Concrete Plain Roofing Tiles, No. 473—1932 " (which specifies the sizes to be $10\frac{1}{2}$-in. by $6\frac{1}{2}$-in., $10\frac{1}{2}$-in. by $6\frac{3}{4}$-in. or 11-in. by 7-in. by at least $\frac{7}{16}$-in. at the centre cross-section and $\frac{3}{8}$-in. at the head and tail) and " Concrete Interlocking Roofing Tiles, No. 550—1934." These specifications give particulars of transverse and permeability tests with which the tiles must comply. Whilst these concrete products, produced by these relatively modern methods, have not been subjected to the real test of time, there is no reason to doubt their durable quality, provided the best materials and workmanship have been employed in their manufacture. The appearance of such mechanical units is, of course, much less attractive than that of the richly textured hand-made clay tiles.

## ASBESTOS-CEMENT SLATING, TILING AND SHEETING

Asbestos-cement is now widely used in the manufacture of many building materials, including roofing slates, tiles and corrugated sheets, wall boards, rainwater goods, felt, etc.

As implied, this material is composed of asbestos and cement. The latter is ordinary Portland cement. Asbestos is a silky fibrous mineral existing in veins in metamorphized volcanic rocks. It is found chiefly in South Africa, Rhodesia, Canada, United States of America, Russia and Cyprus. There are several varieties, but white asbestos, which is a compound of magnesia and silica, is that principally used.

The first stage in the manufacture of asbestos-cement is the separating of the fibres of asbestos. This is accomplished after the quarried rock has been broken into smaller pieces, dried, crushed and passed through a vibrating screen. The fibres are mixed with water and cement, in the approximate proportions of 1 part asbestos to 7 parts cement. This takes place in a machine having a revolving drum with blades attached, and the operation is continued until the asbestos is closely blended with the cement and the fibres are arranged in a uniform direction.

The mixture is now transferred to another machine which has a revolving cylinder of fine sieve wire. The excess water drains through the sieve, leaving on the cylinder a thin film of the mixture, which is then transferred to an endless moving blanket. The film is conveyed by the blanket to a large forming cylinder, where a sheet of asbestos is gradually built up, layer by layer, until the required thickness is obtained. As the mixture passes over the blanket and forming cylinder, the asbestos fibres are uniformly distributed and drawn lengthwise in the direction of the movement to form a tough-woven fabric.

An operative slits the sheet, which is then removed to a platen where it is allowed to mature in the form of a flat sheet, or the sheets are stacked ready for further processing. Partly matured sheets required for slates, tiles and corrugated sheets are submitted to a high degree of pressure in a powerful hydraulic press.

Roof coverings made of this material are tough, durable, fire-resisting and light in weight. The average weight of asbestos-cement covering is only $3\frac{1}{2}$-lb. per sq. ft. (compared with 10 and $14\frac{1}{2}$-lb. for slates and clay tiles respectively) and therefore an economy in timber results when it is applied to wood roofs, as the spars to which the battens are fixed may be spaced up to 2-ft. 6-in. centres. The larger units, such as corrugated sheets and tiles, are especially suited for large spanned buildings of the factory type, where steel trusses are employed, as the covering is fixed direct to the purlins. Here, again, because of their lightness in weight, the employment of asbestos-cement sheets, etc., results in an economy in the sizes of the members of the trusses. Compared with hand-made clay tiles, the chief demerits of asbestos-cement slates and plain tiles are the lack of texture and their true mechanical appearance.

The sizes and methods of fixing some of these asbestos-cement coverings are included in the following description.

ASBESTOS-CEMENT SLATES.—These are made in the following shapes: (*a*) rectangular, (*b*) diamond and (*c*) honeycomb.

(a) *Rectangular Slates.*—There are four standard sizes, namely, 24-in. by 12-in., 20-in. by 10-in., $15\frac{3}{4}$-in. by $7\frac{7}{8}$-in. and $11\frac{3}{4}$-in. by $5\frac{7}{8}$-in.[1] The thickness varies slightly with the size and is expressed in millimetres; the approximate maximum thickness is $\frac{3}{16}$-in. They are obtainable in several colours, including natural grey, green, green-brown and russet-brown. They are laid to give a bonded appearance, and the principle is similar to that described for ordinary slating in Chapter Five, Vol. I. The same terms also apply. Thus, as shown here at A, Fig. 47, each slate is centre-nailed with two nails. The lap is usually 3-in. and occasionally 4-in. The gauge is found in the usual manner, and, as indicated at A, equals $\frac{\text{length of slate} - \text{lap}}{2} = \frac{20 - 3\text{-in.}}{2} = 8\frac{1}{2}$-in. The nails should be of copper or composition and be $1\frac{1}{4}$-in. long. In addition to being twice nailed, each slate (excepting those of the smallest size) is secured at its tail by means of a copper *disc rivet* (see enlarged sketch B). As shown at A, the discs are placed on the course of slates next but one below that of the slates to be riveted with the upturned rivets between the side joints of the slates immediately below. The rivet is passed through the hole formed near the tail of the slate to be fixed and bent over it, after which the slate is nailed.

A further difference between asbestos-cement and ordinary slating occurs at the eaves. Whereas the latter is provided with a double eaves course, an asbestos-cement slated roof has three thicknesses at the eaves. As shown at A, there are two short courses below the top course of full size slates. Two of these under-eaves slates are obtained from one of full size by means of a saw, the cut being made at the gauge distance from one end. Thus, in the example, the length of the two pieces will be $8\frac{1}{2}$ and $11\frac{1}{2}$-in. ($20 - 8\frac{1}{2}$-in.). The shorter slates are centre-nailed and form the first under-eaves course, and the longer pieces are used for the second under-eaves course; the latter are nailed in the centre near the tail, in addition to being twice head-nailed (see A).

The preferred minimum pitch is 30°, although this is sometimes reduced to 25° and the lap increased from 3 to 4-in.

The groundwork for these slates is that described for ordinary slating, but, as already stated, on account of their extreme lightness the spars may be spaced at a greater distance apart up to a maximum of 2-ft. 6-in. centres.

A half-round ridge capping of asbestos-cement is used for this slating. These caps are in 2-ft. lengths, tapering from $8\frac{1}{2}$ to $7\frac{7}{8}$-in., $\frac{1}{4}$-in. thick, laid with 2-in. laps and secured by 3-in. screws at each lap and in the centre of each length. Washers are used in conjunction with these screws (see p. 124). Hips are also formed with these caps.

Some of the merits of asbestos-cement have been stated in the preceding column. In addition, such slates are much cheaper than good quality natural slates. The appearance of these artificial slates, chiefly because of their mechanical neatness, is generally considered to be their least satisfactory feature.

(b) *Diamond or Diagonal Slates.*—These are square shaped, of $15\frac{3}{4}$ and $11\frac{3}{4}$-in.

[1] These are specified in the B.S.S. for "Asbestos-Cement Slates and Unreinforced Flat Sheets and Corrugated Sheets, No. 690—1936."

length of side, with two of their opposite diagonal corners cut off or shouldered. They are laid to a diagonal pattern, with the uncut corners or points at the head and tail. The slates in each course butt against each other at the shoulders only. Each is secured with two nails fixed just above the shoulders and by a copper disc rivet at the tail corner. The recommended minimum laps are $2\frac{3}{4}$, 3, $3\frac{1}{2}$ and 4-in. for 40°, 35°, 30° and 25° pitches respectively. The fussy appearance of roofs covered with these units has, apparently, a limited appeal.

(c) *Honeycomb Slates.*—With exception that their tail corners are removed, they are similar to (*b*).

Asbestos-cement Pantiles.—Whilst these resemble clay pantiles in appearance, there are several differences between the two. Thus : (1) asbestos-cement pantiles are thinner—only $\frac{5}{16}$-in. thick, (2) their opposite diagonal corners are not splayed, but instead each tile has its two opposite edges removed for a length of 4-in. (equal to the lap) and for a depth equal to the thickness, (3) they are nibless, (4) they are twice holed, and (5) they are made in one colour only, that of russet-brown. They are in two sizes, namely, $15\frac{3}{4}$-in. by $13\frac{1}{4}$-in. and $15\frac{3}{4}$-in. by $9\frac{1}{16}$-in. As the recommended head lap is 4-in., the gauge equals $15\frac{3}{4}$-in. $-$ 4-in. $= 11\frac{3}{4}$-in. The side lap is $1\frac{7}{8}$-in. A sketch of a tile is shown at E, Fig. 47, a plan showing the head lap is given at D, and the cross-section at C shows the side lap.

The method recommended for fixing these tiles is to partly fix a 2-in. nail through the right-hand hole (which is about $1\frac{1}{2}$-in. from the head), followed by a $1\frac{1}{2}$-in. nail driven home in the second hole (1-in. from the head) and, finally, the first nail is carefully driven further until the roll just binds on the tile below.

The groundwork is as described for clay pantiling.

Purpose-made eaves pantiles are available in the large size, the tail being stop-ended by a vertical portion shaped at its upper edge to the roll. The necessity for pointing and infilling with pieces of tile, as in clay pantiling, is thereby avoided. These stop-ended eaves tiles are laid upon a $5\frac{1}{2}$-in. wide strip of asbestos-cement, nailed to the batten, and overhanging the eaves gutter.

As stop-ended pantiles are not made in the small size, the eaves of a roof covered with these smaller units are formed in the following manner : Narrow under-eaves strips (see above) are nailed to the fascia or batten, and the eaves pantiles are bedded on them and the ends pointed in cement mortar. To provide a key for the latter, it is recommended that a strip of expanded metal be secured and used to cover the under-eaves strips.

Two forms of rounded hip tiles are used. Both are $15\frac{3}{4}$-in. long, but one is $10\frac{1}{4}$-in. wide and 5-in. high, whilst the other is $12\frac{1}{2}$-in. wide and 4-in. high. These are roughly lined with fine concrete to afford a key for the necessary cement mortar bedding. The flatter type is used for hips of low pitches.

Special double roll pantiles are used for left-hand verges to give a symmetrical appearance. Undercloaks are provided by using plain narrow strips (similar to those for eaves) covered with expanded metal to receive the cement mortar upon which the verge pantiles are bedded.

Purpose-made *twin* pantiles are used at hips and valleys, as ordinary pantiles used in these positions are sometimes difficult to secure after they have been cut to shape and only small triangular pieces remain. These purpose-mades are made in both large and small sizes. Thus, the larger size is $15\frac{3}{4}$-in. long by $24\frac{3}{4}$-in. wide ; it has the appearance of two tiles when fixed, the left and right curved portions being $13\frac{1}{4}$ and $11\frac{1}{2}$-in. wide respectively. These can be securely fixed after they have been cut to the required splay.

This is a cheap, durable, fire-resisting and effective covering.

"Turnall" Trafford Tiles[1] (see S, Fig. 47).—These large tiles are of 3-ft. 8-in. standard width, 4 to 10-ft. long with 6-in. increments, and $\frac{1}{4}$-in. thick. Each sheet has four 2-in. deep corrugations alternating with flat portions. They are fixed to steel purlins by $\frac{5}{16}$-in. diameter *hook bolts* (see F, Fig. 47) and to wood purlins by $4\frac{1}{2}$-in. long *driving screws* (see J). The maximum distance apart of the purlins is 4-ft. 6-in. ; the head lap is 6-in., and the side lap is approximately one corrugation of $3\frac{1}{2}$ to 4-in. (see S). The tiles are laid right to left, commencing at the eaves and working upwards. With exception of the first tile, those in the bottom course have their top right-hand corners mitred. In general, the remaining tiles have their top right-hand and bottom left-hand corners splayed. Eaves, filler pieces, ridges, etc., and the method of fixing are similar to those described below in connection with corrugated sheets. They are obtainable in standard colours of natural grey, red and russet-brown.

These tiles provide an excellent covering, especially for large spanned roofs of the industrial type.

These sheets are also reinforced with meshed wire, and because of their additional strength the purlin spacing can be increased to a maximum of 5-ft. 6-in.

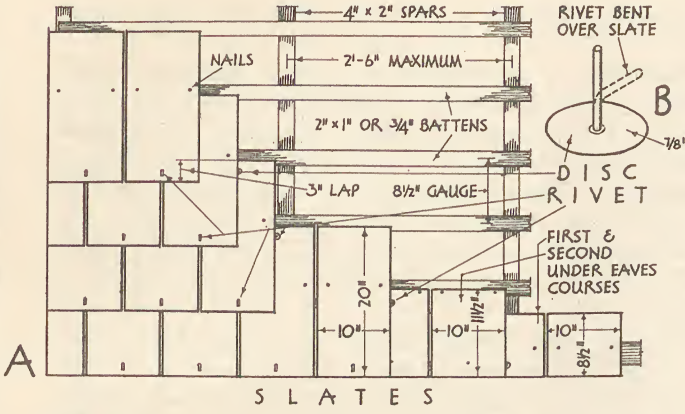
Corrugated Sheets.—Two examples of corrugated sheeting are illustrated in Fig. 47, namely, "Everite Bigsix" Corrugated Sheets[1] and Standard Corrugated Sheets.

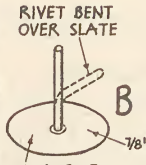
"*Everite Bigsix*" *Corrugated Sheets.*—These are $41\frac{1}{2}$-in. wide, 3 to 10-ft. long in 6-in. rises, and $\frac{1}{4}$ to $\frac{9}{32}$-in. thick. There are $7\frac{1}{2}$ corrugations per sheet at a pitch of $5\frac{3}{4}$-in. and their overall depth is $2\frac{1}{8}$-in. A part cross-section is shown at Q, and the boldness of the design may be gauged by comparing it with the standard corrugated sheets shown at R and having an average depth of corrugation of 1-in. only. The head lap is 6-in. (see L) and the side lap is $1\frac{1}{2}$ to 2-in. (see Q).

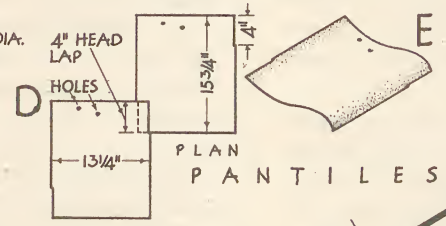
These sheets are fixed direct, with the smooth surface uppermost, to either wood or steel purlins. The detail at L shows the method of fixing to timber purlins. The latter are secured to the principal rafters of the mild steel trusses by angle cleats, as described in Chapter Four, Vol. II. The maximum spacing of the purlins is 4-ft. 6-in., and, because of the light weight of this covering material, the 8-in. by 3-in. wood purlin shown will be adequate for trusses spaced up to 14-ft. centres. The sheets are always fixed through the crowns of the corruga-

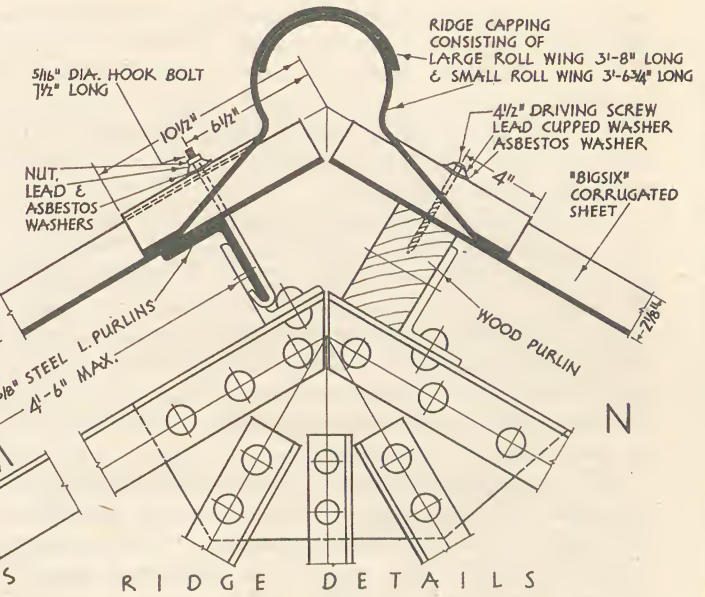
[1] These and the aforementioned slates and tiles are manufactured by Messrs Turner's Asbestos Company.

# ASBESTOS-CEMENT SHEETS ETC



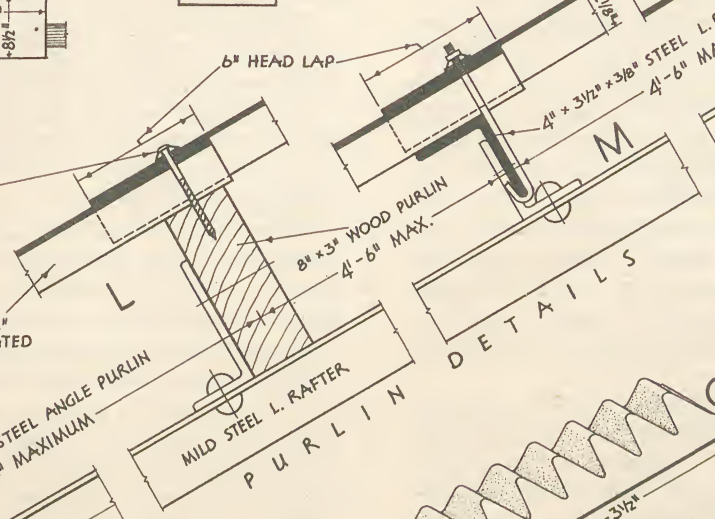



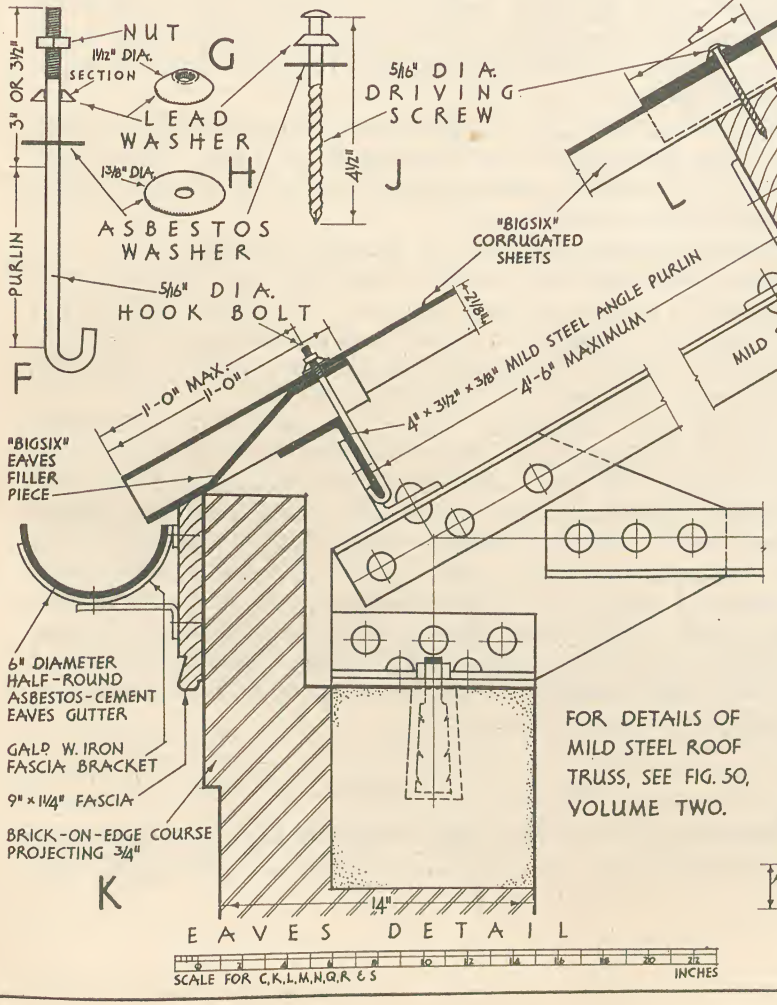


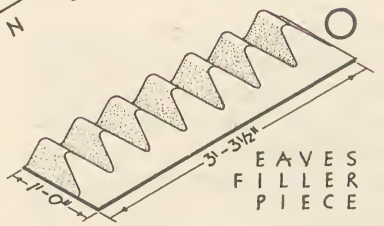



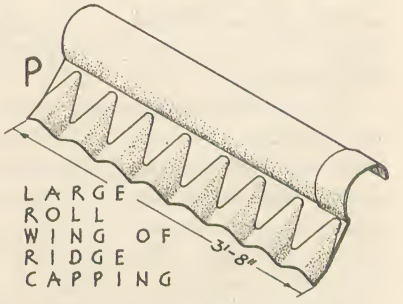


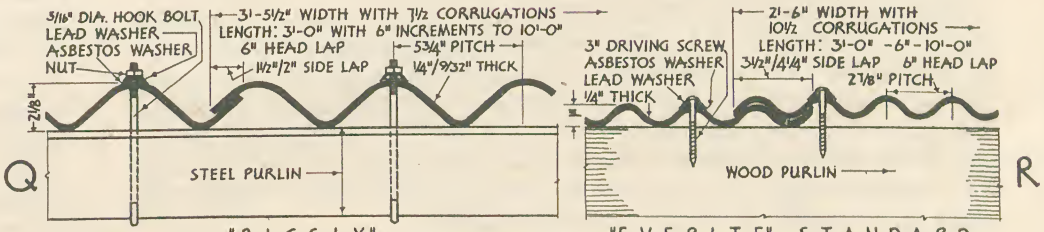


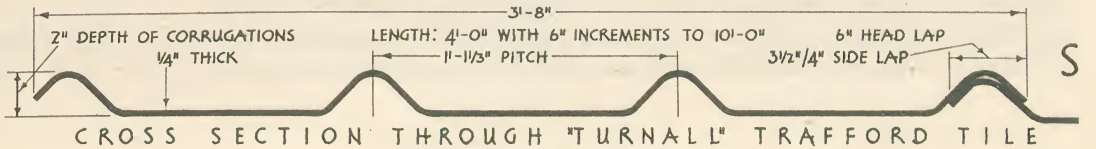



SCALE FOR C,K,L,M,N,Q,R & S — INCHES

SCALE FOR A,D,E,O & P — FEET

FIGURE 47

tions, $\frac{11}{32}$-in. diameter holes being drilled by an ordinary brace and bit to receive the $\frac{5}{16}$-in. diameter galvanized screws which are 4½-in. long (see enlarged sketch J). These are driven in, and a watertight joint is assured if, as shown, an *asbestos washer* H and a *lead-cupped washer* G above it are employed. A sheet is secured at six positions, namely, two at the head, two at the tail and two at the intermediate purlin, the screws being adjacent to the side laps and in similar positions to those shown at Q.

The alternative connection to a steel purlin is shown at M. A $\frac{5}{16}$-in. diameter *galvanized hook bolt* F is used for this purpose. The length of this bolt depends upon the size of the purlin and is either 3-in. (for intermediate fixings) and 3½-in. (for lapped connections) longer than the flange of the purlin. Thus, for the 4-in. by 3½-in. by ⅜-in. purlin shown (which is adequate for trusses spaced up to 14-ft. centres), the hook bolts are either 7 or 7½-in. long. The hook is engaged in the edge of the purlin and is made secure by a nut ; lead-cupped and asbestos washers are again used to ensure watertight joints. Each sheet is fastened at six points as stated above. The cross-section at Q shows two hook bolts at the side joint.

The eaves detail at K includes an *eaves filler piece* which is used to fill in the underside of the corrugations. A sketch of this unit is shown at O. The depth and pitch of the corrugations are similar to those of the general sheeting, and when hook bolted (or screwed, if the purlin is of timber) a tight fit results and weather is effectively excluded. Alternatively, patent close-ended corrugated eaves sheets are available. The unsupported overhang of the sheets should not exceed 1-ft. and therefore, as shown, the bottom purlin should be placed well down the slope.

The asbestos-cement ridge shown at N is in two pieces ; the left-hand piece (see sketch at P) has an external collar or flange and is slightly longer than the small roll wing which has an internal collar. The corrugations of the wings fit closely those of the sheets. These wings and the upper ends of the sheets are secured by either hook bolts (see on the left of the detail N) or driving screws shown on the right. The top purlins must be correctly positioned, and, as shown, the fixings should be 6½-in. from the centre.

These sheets may be fixed from left to right or vice versa, commencing at the eaves. If laid from left to right, the first sheet is fixed uncut, but the remaining sheets in the eaves course must have the top left corner splayed. An ordinary hand saw is used for this purpose. The remaining sheets (with certain exceptions, such as at verges and ridge) have both top left and bottom right corners also cut. Each splay cut removes a corner which measures 6-in. (head lap) along the " vertical " edge and 2-in. (side lap) along the " horizontal " edge. The sheets can be thereby correctly shouldered or mitred.

These corrugated sheets, because of their strength, durability, fire-resisting and heat insulating qualities, are particularly suited for large roofs of buildings such as factories, workshops, offices, garages, gas works, generating stations, farms, etc. Low initial and maintenance costs and speed of construction are additional merits.

" Bigsix " sheets are also made reinforced with ½-in. meshed wire. Because of their additional strength the maximum purlin spacing may be increased from 4-ft. 6-in. to 5-ft. 6-in.

*Standard Corrugated Sheets.*—The dimensions of four standard " small section corrugated sheets " are specified in the aforementioned B.S.S. No. 690—1936. The overall depth of corrugation is either 1 or 1⅛-in. The cross-section at R is through the side lap of sheets manufactured by Messrs Turner's Asbestos Company. The width is 2-ft. 6-in., the lengths vary from 3-ft.—6-in.—10-ft., and the thickness is ¼-in. There are 10½ corrugations per sheet of 1-in. depth and 2⅞-in. pitch. The head lap is 6-in. and the side lap is equal to approximately 1½ corrugations or 4¼-in. The spacing of the purlins is up to a maximum of 3-ft. centres.

These sheets are fixed as described for the " Bigsix " sheets, two ¼-in. diameter hook bolts (2 to 2½-in. longer than the steel purlin) or driving screws (3-in. long) being provided near the side lap at each purlin. Lead-cupped and asbestos washers (slightly smaller than those shown at G and H) are used to render the joints watertight. The ridge capping, in two pieces, is slightly smaller in the wing than that shown at N, and the top purlins are arranged to allow the fixings to be 5½-in. from the apex.

Dimensions of what are called " large section corrugated sheets " are also listed in the above specification. The overall depth and pitch of the corrugations are 2 to 2⅛-in. and 5¾-in. respectively, the width is 41½ to 43-in., and the length and thickness are as stated above.

Curved sheets to a radius from 3-ft. 6-in. upwards are available.

Galvanized Corrugated Iron Sheets.—These have been used extensively for covering roofs of sheds, workshops, huts, etc. The standard sizes are 2-ft wide, 4-ft.—6-in.—10-ft. long and of 18, 20, 22, 24 and 26 gauge ; some 2½-ft. wide sheets are also made. They are fixed through the crowns of the corrugations by hook bolts, screws and nails, with curved washers.

Such covering rusts comparatively quickly, especially at the connections, unless it is protected by painting at suitable time intervals. It has been largely superseded, particularly for better class work, by the aforementioned asbestos-cement products. The latter are more durable and do not require to be painted.

Protected Metal Corrugated Sheets.—These consist of a light gauge steel core which is adequately protected against corrosion by being entirely encased by asphalt saturated asbestos felt, the latter being securely bonded to the steel under high pressure. The natural colour is black, but aluminium and other colours can be imparted by an additional outer coating. This roofing material is strong, durable, light in weight and heat insulating. Cellactite and Robertson Protected Metal are examples of this covering.

## STONE SLATING

The material used for *stone* slated roofs is either sandstone or limestone and *not slate*. As explained on p. 97, Vol. II, a true slate is a metamorphic sedi-

mentary rock, and slates are produced by splitting the block of slate along the cleavage planes (see also Chapter Five, Vol. I). Sandstones and limestones are sedimentary rocks (see pp. 88-94, Vol. II), and those converted for roofing purposes are highly stratified and capable of being split (known as *fissile*) along the natural bed or bedding planes (see also " Tilestones," p. 89, Vol. II).

Some of the quarries from which these stone slates are obtained exist in Yorkshire, the Cotswold district, Northamptonshire, Rutland, Somerset, Dorset and Sussex. Certain of the original quarries are worked out. The Yorkshire stone is sandstone, and that from the Cotswolds is an oölitic limestone.

Whilst true slates of good quality are practically impermeable, those used in stone slating are not. It is for this reason, and also because the blocks of stone cannot be readily cleft into very thin slabs, that stone slates are much thicker than true slates. Yorkshire stone slates, grey to brown in colour, which often darkens on exposure, are obtained by splitting the blocks along their bedding planes with hammer and chisel or wedges. Cotswold stone, greyish-brown in colour and coarse grained, is readily split by a hammer after the blocks have been allowed to stand during the winter and exposed to frost action.

Stone slates vary considerably in size, shape and weight. Yorkshire sandstone slabs are the largest, thickest and heaviest. The limestone slates from Sussex are also thick and heavy. Those from the Cotswold district and Northamptonshire are generally lighter, as they are smaller and thinner. They are all used in random sizes. They are rough in texture, uneven in thickness, and some of the Cotswold slates especially are very irregular in shape. The exceptional beauty of well designed roofs stone slated by skilled labour is due to these qualities and to their agreeable colour.

Hanging and Pitch.—The old method of hanging these stone slates is by wood pegs. Sound oak pegs are tightly driven into holes drilled near the heads of the slates to receive them. The number of pegs per slate varies from one to three, according to the size and weight of the slates. Whilst this method is still adopted, there are certain objections to it. Thus, the pegs may decay, or they may work loose on account of shrinkage, or they may be broken by shear stress, especially if the slabs are exceptionally heavy and steeply pitched. It is therefore considered preferable to use for this purpose either brass screws or stout copper or composition nails.

Another traditional method consisted of bedding the stone slates on mortar placed over roof boarding between thin horizontal battens. This is objected to as the timbers are liable to decay owing to the lack of ventilation and dampness, which latter condition may exist for some considerable time before drying out. Gradual disintegration of the slates may also result.

The pitch given to stone slated roofs depends upon the weight of the covering. Thus, those covered with heavy Yorkshire stone slates, especially if pegged, are given a pitch varying from 25° to 35°. Steeper pitches are given to roofs when lighter stone slates are used. Thus, in the Cotswolds, the pitch varies from 47° to 60°, 55° being common.

The slates are of random sizes in width as well as length ; the latter may vary from as much as 36-in. to less than 6-in. They are sorted on the job, the slater using a special rule for the purpose.

Peculiar names are sometimes given to the slates according to their size. In the Cotswold district, for instance, a 23-in. long slate is known as a " long sixteen ". The following are additional local names with their lengths in brackets : " long fifteens " (21½-in.), " long fourteens " (20-in.), " long thirteens " (18½-in.), " long twelves " (17-in.), " long elevens " (15½-in.), " long wippets " (14-in.), " long nines " (12½-in.), etc. The above are in " shorts " as well as " longs," the former being ¾-in. less than the latter. Hence a " short sixteen " is 22¼-in. long and a " short nine " is 11¾-in. in length. A " short beck " is 8½-in. long. A " muffity " is 8-in. long, and the length of a " tant " is 5¼-in (see A and B, Fig. 48).

The longest and thickest slates are laid at the eaves and the lightest and thinnest at the ridge. The gauge varies accordingly. The diminution is not regular. Thus, there may be three courses laid to an 8-in. gauge, followed by two at 7-in. gauge. Occasionally the gauge of a course may be slightly in excess of that preceding it.

Lap.—This depends upon the pitch, degree of exposure and size of slates. A common lap is 4-in., although for a steeply pitched roof, such as is seen in the Cotswold district, it may be much less. A uniform lap is not always maintained ; thus, whilst a 3-in. lap may be given to the slates near the eaves, this may be gradually reduced to 2-in. at the ridge.

Eaves Detail.—A typical example is shown at B, Fig. 48. This shows a stone wall and a cast iron gutter supported by adjustable brackets on bars driven in at the bed joints (see Q, Fig. 75, Vol. I). Heavy slates, sometimes called *cussomes*, are used to form the under-eaves course. These are bedded on mortar, slightly inclined (about 15°) and projecting 5 to 8-in. They are tailed down by the first batten, as shown, and the heads are notched at the spars as required. Tilting is thereby prevented. The next course, providing the double eaves course, is followed by a course of *followers*. The traditional method of hanging by oak pegs is shown. The dimensions of the gauges and lengths of margins give some idea of a typical arrangement of courses.

Ridge Detail (see A, Fig. 48).—Comparing this with B, it will be seen that the slates at the ridge are much smaller than those at the eaves, the lap is 2½-in. and the slates are shown fixed with either screws or nails.

The thickness of the slates at the eaves is about 1½-in. (these often taper as shown) and that at the ridge is only about ½-in. Long sixteens, long fifteens, short fifteens, long twelves, short nines and short becks (see above) are shown dimensioned in these details. It will be observed that the gauge varies from 10 to 4½-in.

The finish at the ridge is traditional, and as such is considered most suitable for this type of covering. These stone ridges are produced from 9-in. wide blocks of stone which are from 2 to 3-ft. long ; a series of parallel cuts, 1½ to 1¾-in. apart, are made by the saw and each V-shaped unit is then cut square at the apex and lower edges. These are bedded, jointed and pointed in mortar.

Half-round clay ridge tiles, buff coloured, are sometimes used with good effect.

Comparatively large timbers are necessary to support the heavy weight of this covering. In the example, 5-in. by 2-in. spars are used at 15-in. centres. They must be strongly purlined.

In both details the traditional method, still employed, of torching is shown. Untearable felt, nailed to the backs of the spars, may be used in lieu of torching, provided pegs (which would penetrate the felt) are not used. For first class work, and in order to maintain an equable temperature within the buildings, the roofs may be boarded, felted, counter-battened and battened, as previously described.

VERGES AND ABUTMENTS.—Verges may be open, with the undercloak projecting some 2 to 3-in., as described for tiling. Alternatively, a very satisfactory finish is provided by a low parapet wall, having a simple coping under which the slates are flaunched with mortar fillets (see Fig. 45). This is known locally as *tabling*, and is often finished with apex stones and kneelers similar to those shown in Fig. 21, Vol. I.

VALLEYS.—Unquestionably, the most suitable form is the swept valley. This is formed in a somewhat similar manner to that shown in Fig. 42, a valley board being used to block out the angle, and two or three stone slates in each course are cut to a wedge shape as required. Usually, courses having three cut slates at the valley alternate with courses each having two specially shaped slates. In the " three cut " courses, the middle slate or *bottomer* has both sides cut to form a wedge shape and the tail may be slightly curved to the sweep ; the slate on each side, called a *skew* or *lye-bye*, has its edge next to it cut to fit. The next course has two wide *skews*, cut and mitred centrally over the bottomer below, with their tails sometimes slightly curved.

Laced valleys (see Fig. 42) are occasionally preferred.

HIPS.—These are preferably avoided, but if adopted, the adjacent slates should be neatly cut to a mitre and lead soakers inserted (see Q and R, Fig. 69, Vol. I).

Whilst this form of covering has a most attractive appearance and has, in the past, been employed most effectively in many parts of the country, it has been largely superseded by materials which are cheaper than, and often greatly inferior to, those obtained locally. As a result the necessary skilled labour for this class of work is relatively scarce.

## SHINGLES

Shingles are thin slabs of wood used to cover roofs and walls. Although they are used extensively in Canada and the U.S.A., where a suitable timber is readily available, they have not been employed to any extent in this country. There are several reasons why, in the past, they have not found favour here, including a scarcity of satisfactory local material, the plentiful supply of many other forms of roofing coverings and the added danger from fire. Regarding the latter objection, experience has shown that in those parts of America where shingles are in general use an exceedingly small percentage of fires have been directly attributed to the covering. Further, shingles can now be rendered fire-resisting by the application of a fireproof paint on both sides.

Formerly, the shingles used in this country were usually of oak and occasionally of elm and teak. They were split or rent, and such hardwood slabs required to be bored to receive the nails.

Within recent years such shingles have been practically superseded by those of western red cedar, imported from Canada. This timber (see Table I) is very durable, light in weight, straight grained and of a reddish-brown colour which assumes an agreeable silver-grey tone when exposed to the weather. It is reputed to shrink less than any other softwood and is resistant to insect attack.

Cedar shingles are either sawn or split.

Sawn shingles are used chiefly. A sketch of one is shown at B, Fig. 49. The length varies from 15½ to 16½-in., 16-in. being the standard. They are obtained in random widths, varying from 2½ to 14-in. They are approximately $\frac{2}{5}$-in. thick at the tail or *butt edge* and taper to ⅛-in. or less at the head. They are cut from quartered logs and should be rift sawn (see p. 4). Such shingles, commonly known as *edge grained*, should always be used for good work for the reasons stated at A. This also shows a sketch of a quarter log, 16-in. long, and a few slabs to indicate that they are sawn with their butts and heads alternating and at right angles to the annual rings. Flat or plain sawn (see p. 4) shingles, known as *slash grained* and produced by a cheaper method of conversion, should never be used except for inferior work, as the shingles, being sawn tangential to the annual rings (see C), will quickly warp, shrink and split when exposed, and they are liable to decay.

Split, cleft or rent cedar shingles are generally considered to be of better quality than the above, but relatively few are used in England. They are certainly stronger than sawn shingles and are regarded as being more durable. They are also thicker and longer, the length being up to 25-in.

Oak shingles are generally hand-split. The size of these varies from 12 to 27-in. by 4 to 6-in. by $\frac{1}{16}$ to ½-in. They are, of course, very strong and durable. Cypress shingles have also a good reputation, but, like those of the oak variety, they are not generally used.

DETAILS (see Fig. 49).—Whilst these refer to cedar shingles, the principles of construction also apply to those of other timbers. As already stated, cedar is very light in weight (shingles weigh approximately 1½-lb. per sq. ft. or about one-tenth that of plain tiles) and consequently a big economy results in the size and/or number of spars. Thus, if 4-in. by 2-in. spars are used, they are usually spaced at 2 to 2½-ft. centres. Neither close boarding nor roofing felt should be used for cedar shingles [1] to ensure a free circulation of air round them. The groundwork is therefore battens fixed direct to the spars. The size of the former

[1] Oak shingles are usually fixed to close boarding,

# STONE SLATING

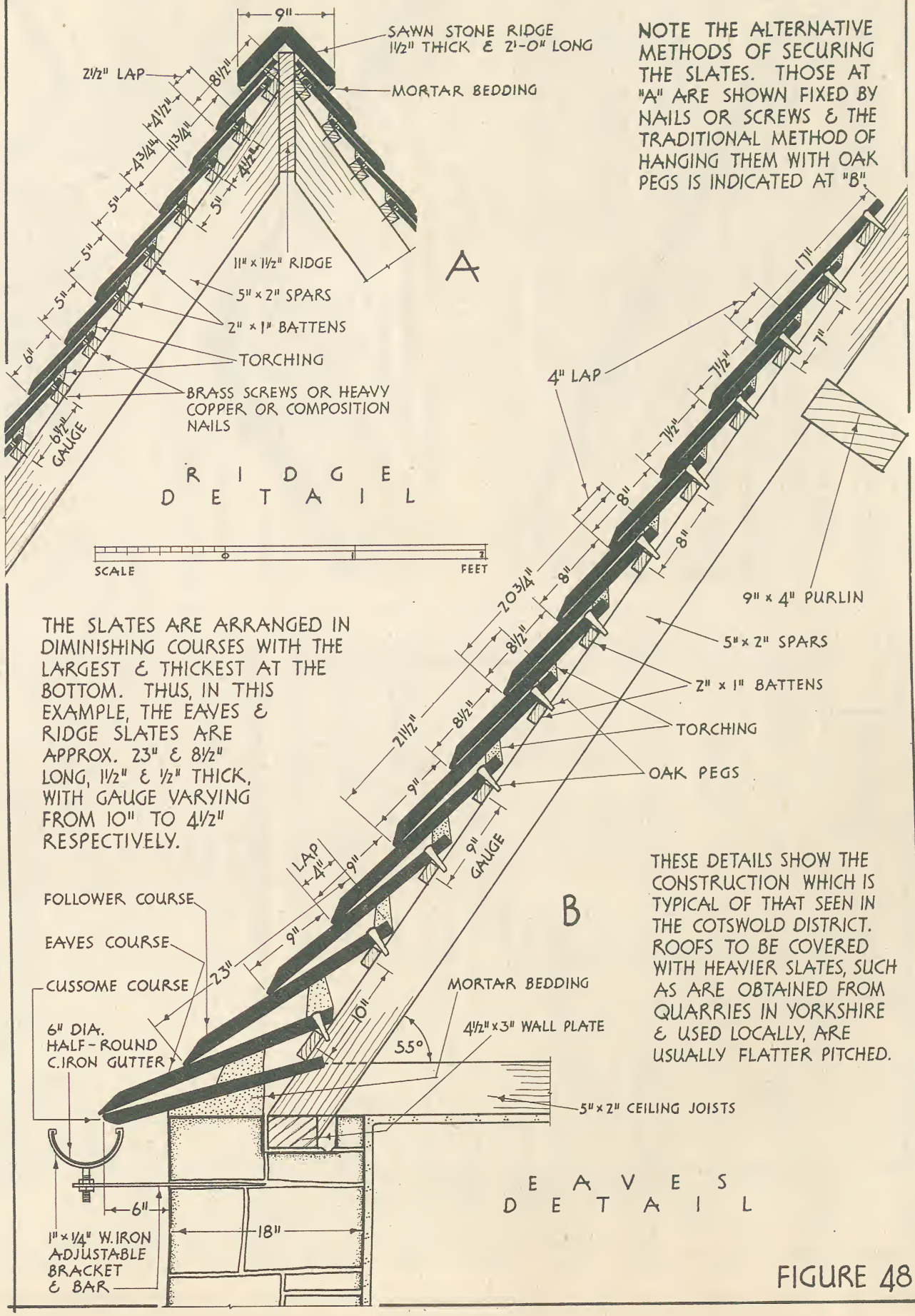
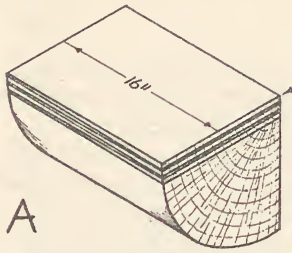

9"
SAWN STONE RIDGE
1½" THICK & 2'-0" LONG
MORTAR BEDDING
2½" LAP
8½"
4½"
4¾"
1¾"
5"
11" x 1½" RIDGE
5" x 2" SPARS
2" x 1" BATTENS
TORCHING
BRASS SCREWS OR HEAVY COPPER OR COMPOSITION NAILS
6½" GAUGE
A
RIDGE DETAIL
SCALE
FEET
NOTE THE ALTERNATIVE METHODS OF SECURING THE SLATES. THOSE AT "A" ARE SHOWN FIXED BY NAILS OR SCREWS & THE TRADITIONAL METHOD OF HANGING THEM WITH OAK PEGS IS INDICATED AT "B".
4" LAP
17"
7½"
7"
8"
20¾"
8½"
21½"
9"
9" GAUGE
9" x 4" PURLIN
5" x 2" SPARS
2" x 1" BATTENS
TORCHING
OAK PEGS
THE SLATES ARE ARRANGED IN DIMINISHING COURSES WITH THE LARGEST & THICKEST AT THE BOTTOM. THUS, IN THIS EXAMPLE, THE EAVES & RIDGE SLATES ARE APPROX. 23" & 8½" LONG, 1½" & ½" THICK, WITH GAUGE VARYING FROM 10" TO 4½" RESPECTIVELY.
LAP 4"
FOLLOWER COURSE
EAVES COURSE
CUSSOME COURSE
23"
10"
6" DIA. HALF-ROUND C.IRON GUTTER
MORTAR BEDDING
4½" x 3" WALL PLATE
55°
5" x 2" CEILING JOISTS
B
THESE DETAILS SHOW THE CONSTRUCTION WHICH IS TYPICAL OF THAT SEEN IN THE COTSWOLD DISTRICT. ROOFS TO BE COVERED WITH HEAVIER SLATES, SUCH AS ARE OBTAINED FROM QUARRIES IN YORKSHIRE & USED LOCALLY, ARE USUALLY FLATTER PITCHED.
6"
18"
1" x ¼" W.IRON ADJUSTABLE BRACKET & BAR
EAVES DETAIL

FIGURE 48

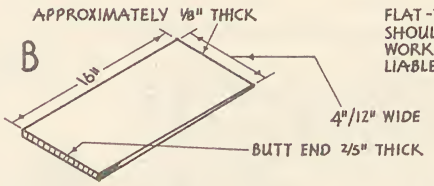
# S H I N G L E S




A

EDGE - GRAINED SHINGLES FROM QUARTERED LOG

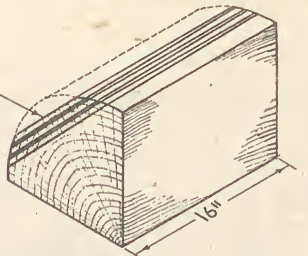
RIFT-SAWN OR EDGE-GRAINED SHINGLES ARE SAWN ALTERNATELY FROM QUARTERED LOGS AS SHOWN & SHOULD ALWAYS BE USED. THEY SHRINK LESS IN WIDTH THAN SLASH-GRAINED SHINGLES & HAVE LESS TENDENCY TO WARP & SPLIT. WESTERN RED CEDAR IS NOW GENERALLY USED FOR THIS PURPOSE, CHIEFLY BECAUSE OF ITS DURABILITY.




B

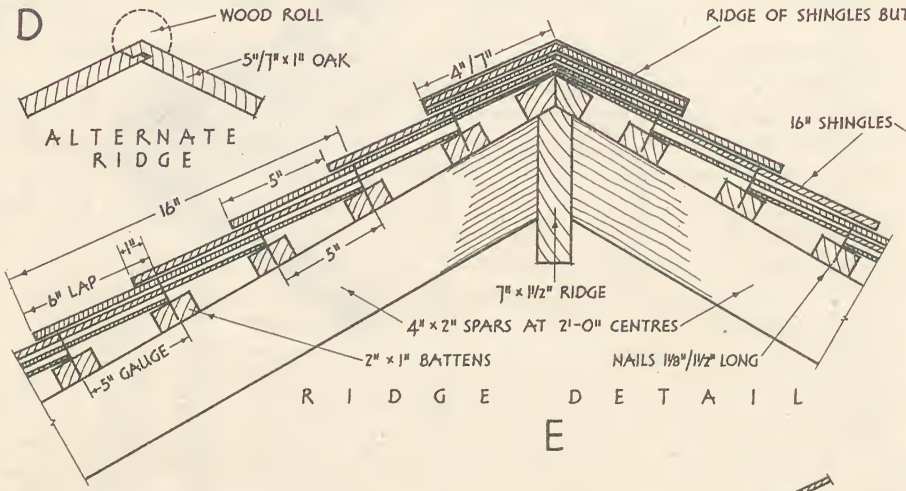
EDGE GRAINED SHINGLE

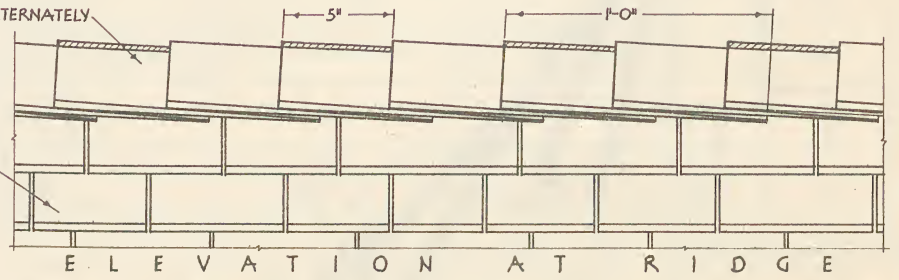
FLAT-SAWN OR SLASH-GRAINED SHINGLES SHOULD NOT BE USED EXCEPT FOR INFERIOR WORK AS ON EXPOSURE THEY ARE VERY LIABLE TO DECAY, SHRINK, WARP & SPLIT.



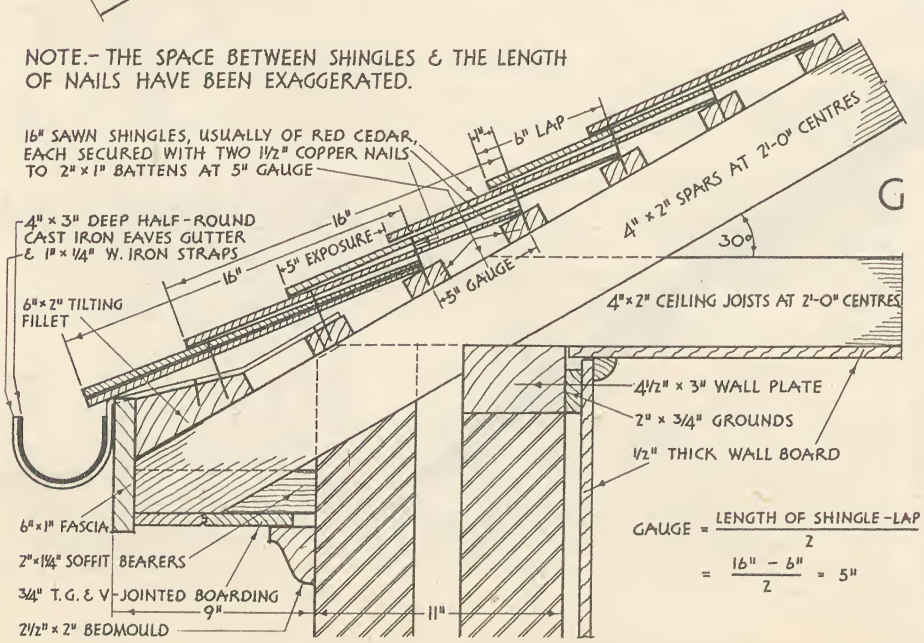

C

SLASH - GRAINED SHINGLES FROM QUARTERED LOG




NOTE.- THE SPACE BETWEEN SHINGLES & THE LENGTH OF NAILS HAVE BEEN EXAGGERATED.


16" SAWN SHINGLES, USUALLY OF RED CEDAR, EACH SECURED WITH TWO 1½" COPPER NAILS TO 2" x 1" BATTENS AT 5" GAUGE
1½"
6" LAP
4" x 2" SPARS AT 2'-0" CENTRES
4" x 3" DEEP HALF-ROUND CAST IRON EAVES GUTTER & 1" x ¼" W. IRON STRAPS
16"
5" EXPOSURE
5" GAUGE
30°
G
6" x 2" TILTING FILLET
4" x 2" CEILING JOISTS AT 2'-0" CENTRES
4½" x 3" WALL PLATE
2" x ¾" GROUNDS
½" THICK WALL BOARD
6" x 1" FASCIA
2" x 1¼" SOFFIT BEARERS
¾" T. G. & V-JOINTED BOARDING
2½" x 2" BEDMOULD
9"
11"
EAVES DETAIL

$$\text{GAUGE} = \frac{\text{LENGTH OF SHINGLE} - \text{LAP}}{2} = \frac{16" - 6"}{2} = 5"$$

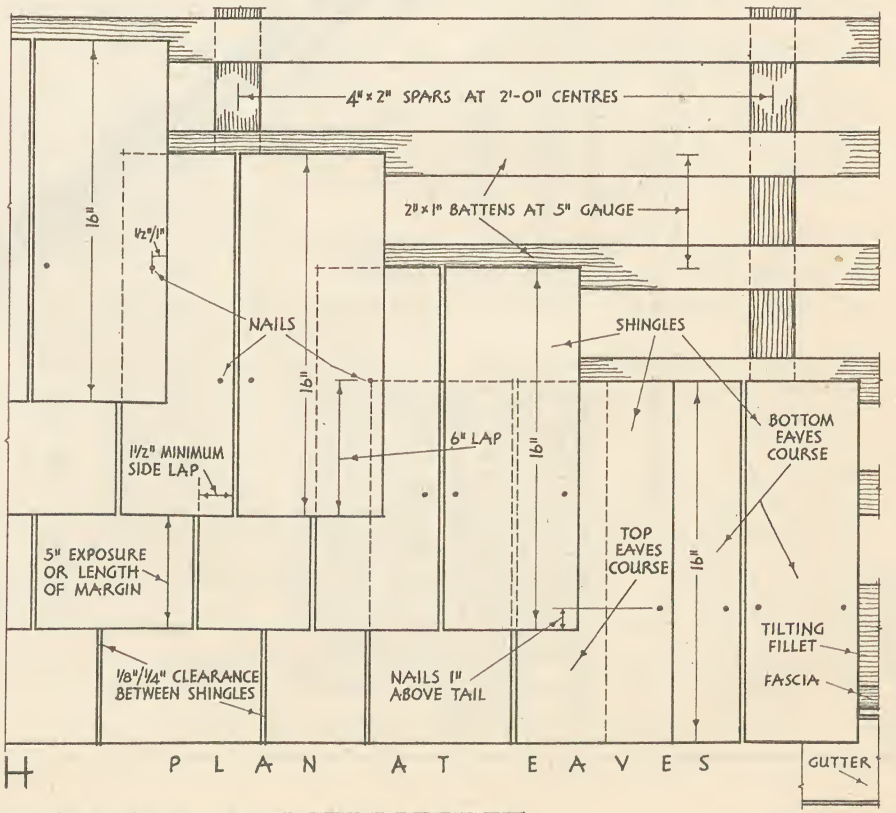



FIGURE 49

varies according to the spacing of the rafters, and 2-in. by 1-in. battens are commonly specified when, as shown, the spars are at 2-ft. centres.

The shingles are laid in random widths. Those wider than 10-in. should not be used, as these tend to curl, and such are therefore split in half. A gap of from $\frac{1}{8}$ to $\frac{1}{4}$-in. should be left between the sides of adjacent shingles to allow for any swelling which may occur (see H). Each shingle is secured with two nails. Pre-boring (forming holes to receive the nails) of cedar shingles is unnecessary. As shown, the nails pass through the shingle immediately below and barely clear the head of the third. Copper (for best work) and galvanized iron nails are used; the length varies from $1\frac{1}{8}$ to $1\frac{1}{2}$-in. These are driven at from $\frac{1}{2}$ to 1-in. from the sides and at least 1-in. above the *exposure line*. The "exposure" is the exposed portion or margin of a shingle, and, as in slating or plain tiling, the length of margin equals the gauge. The latter length is often referred to as the exposure.

The gauge varies with the pitch. A 30° pitch is common, for which a minimum gauge of 5-in. is recommended. This may be reduced to $3\frac{3}{4}$-in. for pitches less than 30°.

On reference to E, it will be seen that the construction differs from slating or plain tiling in that there are at least three thicknesses of shingles (with a possible exception at the eaves, see below) and four thicknesses where the top shingles cover the nails immediately below. The lap is considered to be equal to the distance from the butt (tail) end to the nail holes; in the example the lap is shown to be 6-in.

EAVES (see G).—This is closed and has an overhang of 9-in. As in slating, a double course is provided, having a $1\frac{1}{2}$-in. projection. Sometimes a triple eaves course is formed. Unlike slating, all the double eaves course shingles are of the full length of 16-in. The upper eaves course must break joint with the lower, and the minimum side lap is $1\frac{1}{2}$-in. (see H). The battens are spaced at the gauge apart. It will be observed that the heads of the shingles in each course are at the centre of the batten and that the nails also pass through the middle.

*Note.*—In order to make the construction clear, in both details E and G a relatively wide space has been shown between each course. This has resulted in an exaggerated length of nail. Actually the shingles fit closely, and rarely is a longer nail than $1\frac{1}{2}$-in. required, $1\frac{1}{8}$-in. being common.

As the minimum spacing of ceiling joists for $\frac{1}{4}$-in. thick plasterers' laths is 16-in., it is assumed that the ceiling is to be covered with wall boards (see p. 49.)

The plan at H shows a typical arrangement of the shingles and will help to make clear the above description. Note the random widths, minimum side lap, position of nail holes and the head lap.

RIDGE (see E and F).—The usual finish is shown composed of narrow widths of 12-in. shingles, each pair being butt jointed alternately.

An alternative treatment consists of *saddle boards*, which are long lengths of tongued and grooved oak or elm narrow boards (see D). The end joints should be dovetail rebated or half-lapped. In addition, the joints of the saddle boards may be covered with a wood roll, as shown by broken lines.

Lead-covered ridges are also adopted. These are of the type shown at H, Fig. 73, Vol. I, a wood roll being covered with 5 to 6-lb. lead secured by lead tacks at about 3-ft. intervals.

HIPS.—One form is similar to the ridge shown at E and F, the shingles in adjacent courses being cut-mitred and covered with shingles, lapped alternately at their edges.

A cut and mitred hip with lead soakers is another type, wide shingles being used at the intersection and lead soakers introduced as explained for slating on p. 137, Vol. I. A wood roll may be added.

Lead-covered hips, similar to ridges, is an additional finish.

VALLEYS.—These may be of wide shingles, cut and mitred, with lead soakers. An open lead gutter (see p. 148, Vol. I) is another form, boards being provided at each side to receive the lead. Swept valleys, as described for tiling (p. 110), are also occasionally used.

ABUTMENTS.—Intersections at gable parapet walls, chimneys, etc., are treated with lead flashings, as described for Plumbing, Chapter Six, Vol. I.

VERTICAL SHINGLES.—External wall surfaces can be treated quite attractively and rendered damp-resisting by nailing shingles to battens plugged to the wall at 6-in. to 7-in. gauge (see vertical tiling, p. 110).

## COPPER ROOFING

MANUFACTURE.—Copper is obtained from ores found, on a small scale, in this country (Cornwall) and extensively in the U.S.A. and elsewhere. There are several methods of extracting copper from its ores, depending upon their character. In one, a preliminary operation consists of roasting or calcining the ore which has been previously ground. This eliminates the excess of sulphur. The roasted ore is then smelted (reduced to a fluid condition by intense heat) in a furnace. The crude molten metal is run off into a special bogie or settler where the slag or scum is eliminated. The material which remains (a mixture of copper, iron and sulphur) is granulated in water, cooled, broken up and ground. It is again roasted, smelted and re-granulated. This refining process is repeated until the iron and sulphur are removed, when the final product is cast into bars, called *pigs*. The last operation depends upon the form required. For roofing purposes the copper is either hot or cold rolled into thin sheets. In hot rolling, which is usually required for roofing, the heated pigs or ingots are passed backwards and forwards between rollers until sheets of the required thickness are obtained.

CHARACTERISTICS.—Copper is exceedingly durable, tough, non-corrodible, very light in weight (see p. 130), resistant to fire, malleable, ductile, soft, and an excellent conductor of heat. It has a reddish-brown colour, which, when exposed to the atmosphere for several years, often assumes an attractive pale green colour

called the *patina*. This greenish film of carbonate of copper acts as a protecting coat to the metal below its surface. Copper has a relatively small coefficient of linear expansion, being 0·0000168 per ° C., compared with 0·0000292 per ° C. of lead. As a roofing material copper is superior, but more costly than lead. Unlike lead it does not creep when laid on steeply pitched or vertical surfaces.

Hot-rolled sheets for general roofing are usually specified of " dead soft temper " (condition and degree of hardness) to allow for the hardening (called " work hardening ") which occurs when the sheets are being laid and worked into position.

SIZES.—Sheets are obtainable in any length up to 12-ft., and 6-in. up to 4-ft. in width. When less than 15-in. wide the pieces are known as *strips*, and are usually cold-rolled ; such are used for valley, etc., gutters. The thickness of copper sheets is specified either of Standard Wire Gauge (S.W.G.) or the weight in ounces per square foot. For most roofs 24 S.W.G.[1] (16-oz. per sq. ft.) is used. This gauge is increased to 23 S.W.G. (19-oz. per sq. ft.) for superior work.

Sheets of copper are purchased by the lb. weight, and the so-called *basis price* is that per lb. for sheets not exceeding 14-sq. ft. in area and not less than 24 S.W.G. The dimensions of sheets of basis price area vary, thus : 7-ft. by 2-ft., 6-ft. by 2-ft. 4-in., 5-ft. 3-in. by 2-ft. 8-in., etc. This cost per lb. is increased if the sheets are over 14-sq. ft. in area or are thinner than 24 S.W.G.

GROUNDWORK.—Copper sheets are laid upon t. and g. or butt-jointed boarding [2] of ¾ to 1-in. in thickness. Because of its light weight the size of the timber bearers or spars may be less than those required for lead covering, or, alternatively, the spacing of these timbers may be increased. If used on flat roofs the minimum fall is 1 in 80 (1½-in. in 10-ft.) and the boarding is preferably laid in the direction of the fall, or diagonally, in order that any warping will not obstruct the flow of water. As already mentioned, copper does not creep, and it is therefore especially suited for steeply pitched roofs, domes, etc. The heads of the nails securing the boarding should be punched below the surface and the boarding planed to a smooth finish. The boarding is then covered with felt (preferably) or one or two layers of building paper (see p. 56, Vol. II) to serve as a cushion and an insulating layer to deaden the sound of falling rain. Copper nails should be used for fixing the felt, as iron nails may set up electrolytic action, resulting in the decomposition of the sheeting.

JOINTS.—Although the expansion and contraction of copper, due to changes of temperature, is relatively small, such must not be entirely ignored. Provision must therefore be made for this movement, especially at the side joints. Drips (see p. 144, Vol. I) are not necessary, except in parapet gutters (see p. 132), and instead the *transverse*, *end to end* or *cross joints* consist of (*a*) welts. The *side* or *vertical joints* are in the form of (*b*) wood rolls or (*c*) standing seams.

(a) *Welts*:—That most favoured for jointing sheets *end to end* is known as the *double lock cross welt*. Four stages in the development of this joint are shown at A, Fig. 50. In the first stage the edge is turned up about 1-in. as shown. In the second operation a portion of this edge is turned down. An edge of the adjacent sheet is turned up and engaged in the fold of the first sheet (see third stage). In the final stage these edges are folded down to form the welt, which is about ½-in. wide. The sheets are welted together in this manner until the required total length is obtained. Such a linked up sheet is called a *string*. The welting operation is generally completed in the shop. The strings are then in turn placed in position on the roof. It is usual for the welts to be staggered. This avoids awkward thicknesses appearing at the vertical (side) joints. *Single lock cross welts* (similar to that shown at E) are sometimes used for stringing sheets required for steep pitches or vertical surfaces.

(b) *Wood Rolls*.—These are employed at *side joints* on flat roofs, or those slightly pitched, which may be subjected to traffic. Five examples are illustrated in Fig. 50, all of them providing efficient watertight side joints and permitting lateral movement of the sheets.

The *conical roll* shown at B is much favoured. Copper *clips* or *straps* (similar to the lead tacks described on p. 144, Vol. I), 1½ to 2-in. wide, are placed under the rolls at about 3-ft. centres. The rolls, secured by copper or brass screws, are spaced at a distance apart equal to 3-in. less than the width of the copper sheets, *i.e.*, 2-ft. 5-in. for 2-ft. 8-in. wide sheets—the latter being a common width ; this permits of an approximate allowance of 3-in. for each overcloak and 2-in. for every undercloak. The three stages of development are shown at B, a welt being formed on one side, as shown, in the final stage. Alternatively, the clips may be as shown at D, each secured at the undercloak side by two 1¼-in. copper flat-headed nails.[1]

The four rolls at C differ from the above in so far as each is covered with a strip of copper called a *capping*. In each case the upturned edges of the sheets are welted to the capping. Copper clips (not shown) are provided at 3-ft. intervals, as described above. The *undercut roll* is a good expansion joint. The *square roll* is commonly applied in Scotland. The *round top roll* and the *ornamental roll* are suited, because of their appearance, for pitched roofs ; the shape of the latter roll is only one of several mouldings.

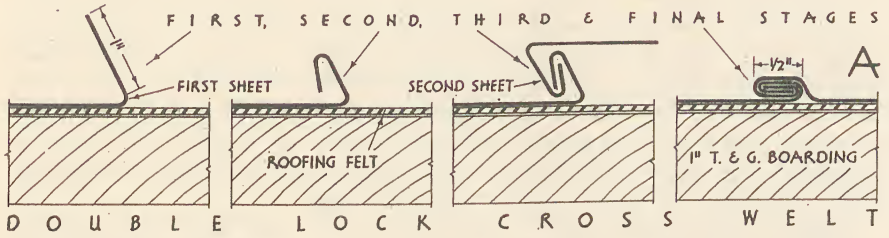
(c) *Standing Seams or Stand-up Welts*.—These are suitable for *side joints* on steeply pitched roofs or flats which are not likely to be subjected to traffic. It is a good expansion and watertight joint. The sheets are first welted end to end, as described above, the strings are then placed in turn on the roof, and the standing seams formed by means of wide lipped pliers (called *seamers*) or dressers (similar to that shown at A, Fig. 76, Vol. I). The stages of development of this joint are shown at D. Copper clips, 1½ to 2-in. wide, are shaped as indicated in the first stage and fixed in alignment at 1-ft. centres, each clip being secured with two 1¼-in. copper flat-headed nails. The edge of the first sheet is turned up 1½-in., that of the second strip is turned up 1¼-in., all of the clips and first

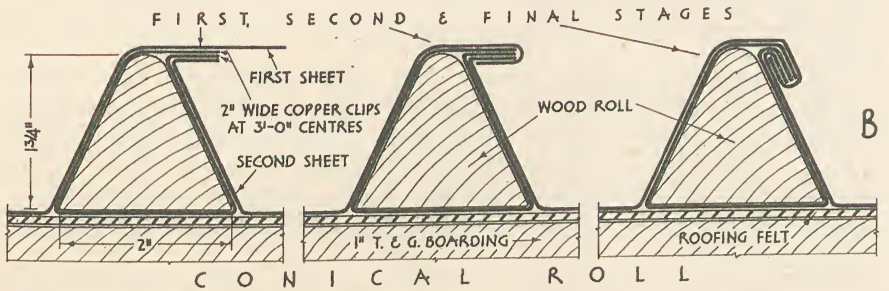
[1] The thickness of 24 S.W.G. is 0·022-in. and that of 23 S.W.G. is 0·025-in.
[2] Concrete roofs are also sometimes covered with copper.

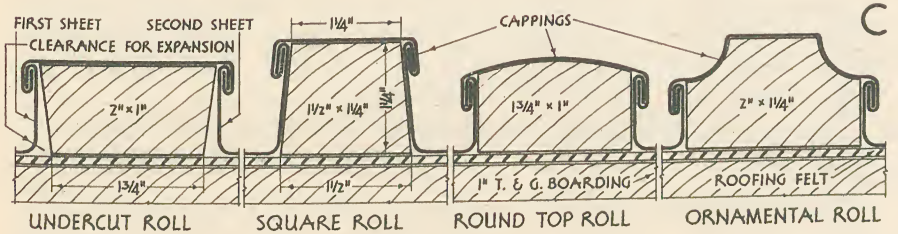
[1] These nails should be without shoulders (enlarged connections between the head and stems), which latter tear the copper when the nails are driven home.

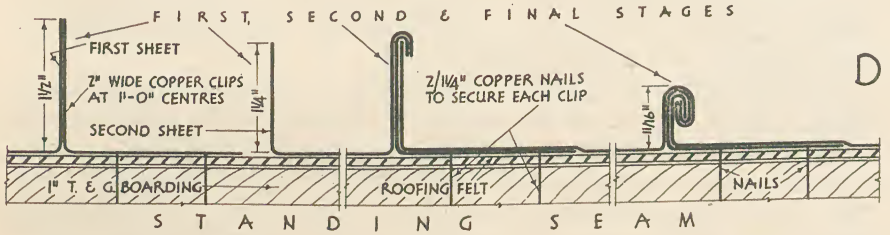
# ROOFING

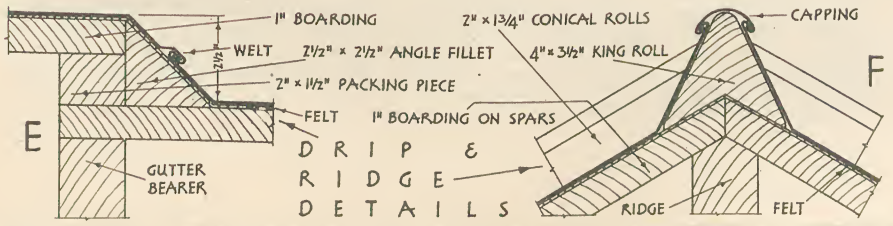
## COPPER



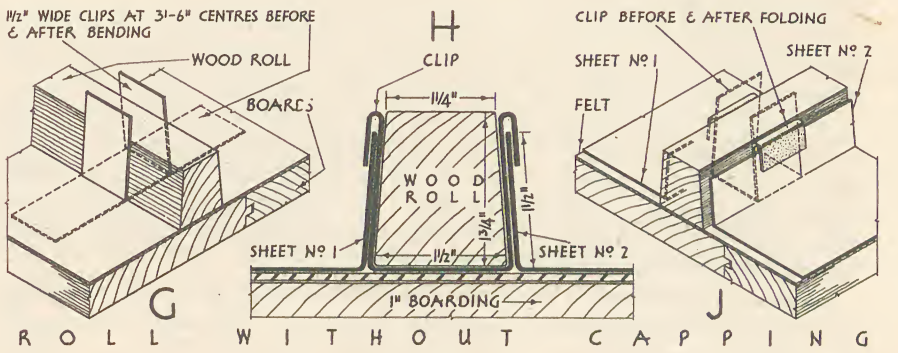



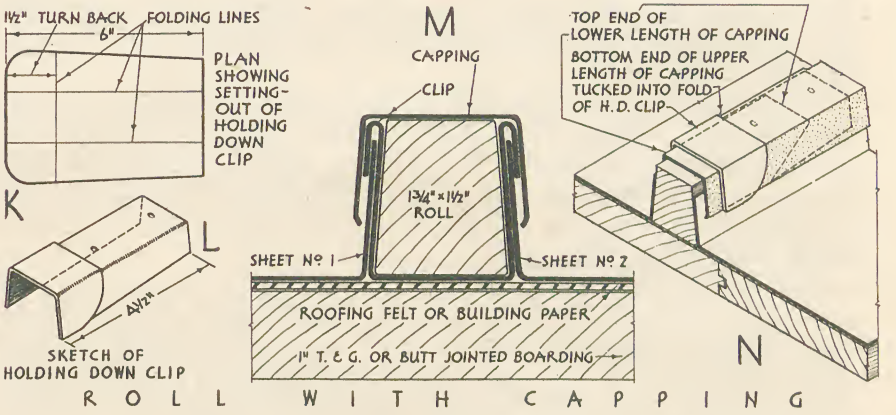



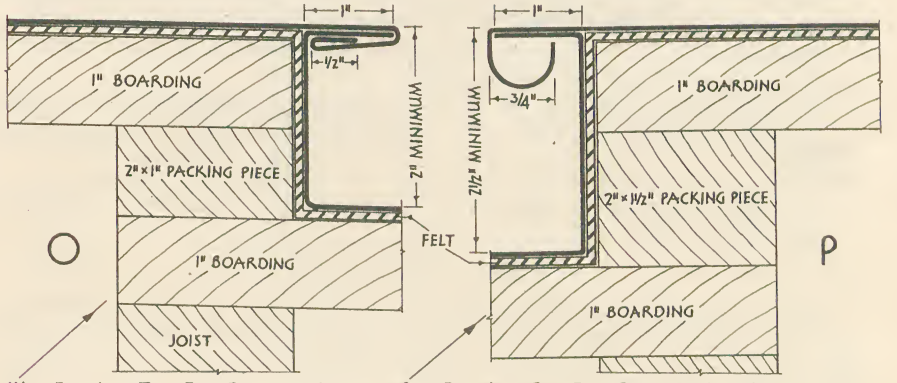




## ZINC



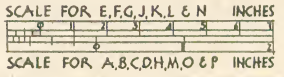




FIGURE 50

sheet are turned over the standing edge of the second sheet (see second stage), and all three are bent over to form a double lock welt, as shown in the final stage. The height of the finished joint is approximately ¾-in.

The setting out of a copper covered roof, therefore, somewhat resembles that of the lead flat shown at A, Fig. 72, Vol. I, the *side joints* consisting of rolls or standing seams, and the *cross joints* being welts, staggered, instead of drips.

DRIPS.—As mentioned on p. 130, drips are only provided in parapet gutters in order to increase the flow of water towards the outlet. As shown at E, the timber construction is similar to that of a lead drip (see Fig. 72, Vol. I), except that an additional 45° angle fillet is fixed. The adjacent copper strips covering the gutter are jointed by a *single* lock cross welt at the centre of the fillet. Sometimes the welt is formed at the top of the fillet.

RIDGES.—A satisfactory treatment at a ridge is shown at F. Here the ridge roll or *king roll* is higher than the adjacent wood rolls. The copper covering the king roll is as described on p. 130 in connection with the rolls at C, a capping being provided and welted to the upturned sheets. The overcloaks of the conical rolls (or the cappings if the rolls are of type C) are widened and welted into the king roll capping.

If the side joints of the copper roof covering are of the standing seam type (D), it is usual for the sheets covering the two slopes to be welted at the ridge intersection and dressed down on one side over the felt covered boarding (butt jointed as shown at F and without the roll). The standing seams forming the side joints are gradually flattened for a distance of about 6 in. down from the apex and folded into the ridge welt.

HIPS are formed as described for ridges.

VALLEYS.—The woodwork is of the usual construction (see J, Fig. 45). Welted joints are formed between the copper strip covering the valley and the sheets covering the slopes. If wood rolls are adopted for the side joints the ends of the rolls are cut short of the intersection and bevelled back, the copper is dressed round the ends and the welted undercloaks and overcloaks are continued and tucked into the valley welt. If the standing seam method has been employed the seams are gradually flattened at the ends and linked into the valley welt.

STEPPED, ETC., FLASHINGS.—These are very similar to those executed in lead and described in Chapter Six, Vol. I.

Copper roof covering in the form of corrugated sheets, tiles, etc., is also obtainable, but there has been only a very limited demand for such in this country.

NOTE.—*In the details shown in Fig.* 50 *the space between the copper at the welts has been exaggerated.*

## ZINC ROOFING

MANUFACTURE.—Zinc is extracted from certain ores, the chief of which are the dark coloured *blende* and the light coloured *calamine*, found in England (on a small scale in Cornwall, Cumberland, Derbyshire and Somerset), Wales, Canada, Poland, Spain, Sweden and the U.S.A. Several methods are adopted for extracting the metal. In one the powdered ore is roasted in a furnace and then heated in horizontal retorts. Here the zinc is volatilized and the vapour is condensed in receivers. The condensed zinc is removed and poured into metal moulds, when it is commercially known as *spelter*. The metal at this stage is brittle. The spelter is re-heated and made malleable, after which it is re-cast into rectangular cakes, allowed to partially cool and finally rolled. It is passed between two sets of rollers until the required thickness is obtained, the direction of rolling in the finishing mill being at right angles to that in the first or roughing mill. The sheets are finally trimmed (sheared) to size.

SIZES.—The standard size of sheets is 7 to 8 ft. long and 3 ft. wide, the latter length being usually adopted. Zinc is specified according to gauge. For best work, 16 Zinc Gauge [1] is used, and 14 Z.G. is the recommended minimum thickness.

CHARACTERISTICS.—Zinc is a white metal with a bluish-grey tint. When exposed to the atmosphere a carbonate is formed which forms a protective coating to the underlying metal. It is brittle at ordinary temperatures. Zinc is a very light roofing material, although the sheets are heavier than copper. It is fairly durable, provided it is used for roofing purposes in atmospheres free from smoke, but it has a relatively short life if subjected to acids. Its initial cost is low.

The coefficient of expansion of zinc is higher than that of copper and is 0·0000291 per ° C., or practically the same as that of lead. Therefore, when applied on flat roofs both rolls and drips must be used to permit of expansion. The minimum fall for flat roofs is 1 in 64 (1½-in. in 8-ft.). Zinc does not creep and it is therefore suitable for steeply pitched roofs.

JOINTS.—The setting out of a zinc covered flat roof is similar to that for lead flats (see A, Fig. 72, Vol. I), (*a*) rolls and (*b*) drips being formed as described below.

The boarding should not be less than ¾-in. thick and, like that for copper and lead covering, it should be laid diagonally or in the direction of the fall. It is generally butt jointed, but t. and g. boarding is occasionally employed. Building paper or felt is used to cover the boarding. This provides thermal and sound insulation, and acts as a cushion.

(a) *Wood Rolls.*—As shown at G, H, J, M and N, Fig. 50, the wood rolls are slightly tapered, and as the zinc sheets placed between them have each side turned up 1½ in., it follows that the rolls are spaced at a distance of 2-ft. 9-in. apart (2-ft. 10½-in. centres) or 3-in. shorter than the width of the sheets. Zinc clips, 1½-in. wide, are spaced at about 3-ft. 6-in. centres under each roll and the latter is then nailed at 1-ft. 9-in. intervals, every alternate nail passing through a

[1] Zinc Gauge should not be confused with the Standard Wire Gauge (see footnote to p. 130.) The Zinc Gauge, unlike the S.W.G., increases in number with the thickness. Thus, the thickness of 14 Z.G. is 0·031-in. (approximately 21 S.W.G.) and the thickness of 16 Z.G. is 0·041-in. (approximately 19 S.W.G.). The weight per square foot of 14 Z.G. is 18·58-oz. and that of 16 Z.G. is 24·57-oz.

clip. Zinc or heavily galvanized wrought iron nails must be used for fixing the rolls. Copper or plain wrought iron nails must not be used for this purpose, as electrolytic action may be set up and result in decay of the metal. A clip before and after being turned up is shown at G.

The sheets, with their long edges turned up 1½-in, are then placed in position and the clips are hooked over the edges as shown at J and the enlarged section H. It will be observed that adequate space is provided to permit of expansion.

The rolls and the turned up edges of the sheets are now covered with zinc cappings. A capping is shown in the section at M. This shows the edges of the capping turned in slightly. The cappings, not exceeding 6-ft. in length, are secured by *holding-down clips*. Such a clip is illustrated at L and is formed from a piece of zinc set out as indicated at K; the lower edge is turned back 1½-in. and the sides are bent down. A clip is secured by two or three nails to the roll over the top end of the lower length of capping, and the bottom end of the upper length of capping is slipped into the fold or turn-back of the clip. A watertight joint, which permits of expansion, is thus assured. A portion of completed roll, including a clip, is shown at N.

In a flat roof, divided by drips as explained below, each roll will be covered with two lengths of cappings secured by a holding-down clip at the centre.

(b) *Drips*.—The spacing of these transverse joints is 6-in. less than the length of sheet employed; thus, for 8-ft. long sheets the drips will be at 7-ft. 6-in. intervals. There are two forms of drips, (i) welted and (ii) beaded.

(i) *Welted Drips* (see O).—The depth must be at least sufficient to allow the welt to clear the cappings of the rolls below, 2-in. being a minimum but 2½-in. is common. The top edge of the lower sheet is turned up and then turned out 1-in. in line with the top of the drip. A welt is formed along the bottom edge of the upper sheet by first of all bending the edge back ½-in. (which stiffens the welt) and then folding this bent edge back 1-in. The joint is then completed by engaging the turned out edge on the lower sheet within the fold of the upper sheet.

(ii) *Beaded Drips* (see P).—The depth must be at least 2½-in. to allow of adequate clearance between the bead and the cappings below. The edge of the lower sheet is turned up and out, as described above. A ¾-in. bead is formed on the bottom edge of the upper sheet by first bending the edge back slightly for ½-in., followed by turning the edge down 1½-in. at right angles and then dressing it over a ⅝-in. diameter rod (called a *beading rod*). This beaded edge is finally fitted over the turned out edge of the lower sheet.

Beads, welts, etc., are formed by the use of a dresser similar to that used for lead and shown at A, Fig. 76, Vol. I.

Steeply Pitched Roofs.—Drips are dispensed with if the pitch of a roof exceeds 1 in 8. The transverse joints are then of the *single* lock cross welt type as used in copper roofing (see p. 132). The welts occur at 7-ft. 9-in. centres when the sheets are 8-ft. long (or 3-in. less than the length of sheets employed) and they are not staggered. They are formed in the following manner: The top edge of the lower sheet is folded over 1¼-in. This sheet is secured by two 4-in. by 3-in. zinc clips spaced along its upper edge, each being twice nailed to the boarding after its lower edge has been bent and engaged in the fold of the sheet. The bottom edge of the upper sheet is then folded under 1-in.; this turn-back is engaged in the fold of the lower sheet and the welt is then completed by applying the dresser. The rolls are, of course, continuous from eaves to ridge, the cappings being in approximately 6-ft. lengths and secured by holding-down clips, as described in the preceding column.

Flashings are somewhat similar to those described for leadwork in Vol. I. The lower edge of a cover flashing is stiffened by forming a ½-in. bead or fold along its lower edge. Similar beads are sometimes formed on the edges of the up-turns of the gutter or roofing sheets.

## THATCH

This roof covering consists of bundles of reeds or straw secured to battens and spars. The thickness of the thatch varies from 9 to 16-in., according to its quality and the pitch of roof. The latter should not be less than 45°. Thatch affords a watertight cover when skilfully applied and undoubtedly the appearance of thatched buildings can be delightfully picturesque. It has, however, several serious demerits, chief of which are its liability to destruction by fire and its tendency to become infested with vermin. It is claimed that reed thatch will last at least sixty years if properly attended to, and many old roofs produce evidence of this. The life of straw thatch is not more than about twenty years. On the other hand, comparatively new thatched buildings have been totally destroyed by fire. The plumber's blowlamp, used to free frozen water pipes and cisterns situated in thatched roofs, has been responsible for many fires. It is significant that many local authorities will not permit the use of thatch (not even when treated with so-called fireproof solution), that there are few skilled thatchers available, and that when thatched roofs on existing buildings become defective the covering is often replaced by materials other than thatch.

Thatching.—Reeds, such as are obtained from the Norfolk Broads, are best used for thatching. They are much longer (up to 9-ft.) than wheat or rye straw, which latter is also used. The material is formed into bundles and tied with tarred twine. The spars are spaced at from 2 to 2½-ft. centres, and 2-in. by 1-in. battens are nailed to them at 8 to 12-in. gauge.

There are several different methods of fixing the thatch, varying with local practice. The reeds or straw must be well soaked with water or fire-resisting solution to facilitate packing, and the bundles are laid with their butt ends pointing towards the eaves. A slope of a roof is thatched in a series of *beds* or strips, the width of a ladder, and extending from eaves to ridge. The thatcher, working on a ladder from right to left, commences at the eaves and packs the bundles tightly sideways and downwards from the right across to the side of the ladder to complete the width of bed. The next course of bundles is packed in a similar manner at 8 to 12-in. above the first (depending upon the length of reed or straw), and this is continued until the ridge is reached. *Withies* (twisted rods of pliable willow twigs, sometimes called *osiers*) are interlaced through and over the bundles at about 2-ft. apart as the thatching proceeds, and these are secured to the spars with tarred twine. In some districts tarred twine is used instead

of withies ; a needle is " threaded " with the twine, the latter is pulled tightly over the straw, passed round a batten and withdrawn to complete the stitch ; an assistant or under-thatcher often assists in this operation. Each bed is raked or combed down to remove loose reeds or straw. Beds are formed in this manner until the slope has been covered. Additional security is provided at verges by placing short horizontal withies (called *scallops*) on top of the thatch at about 2-ft. intervals and securing them with wood *staples* (pieces of withies bent to a U-shape) which are driven into the thatch at about 1-ft. apart. The eaves project from 18 to 24-in. and a horizontal soffit is formed by cutting to a line with a sharp knife.

Ridges are formed of straw. One of several methods of thatching a ridge is as follows : The bundles, about 1½ to 2-ft. long, are stretched over the apex and caused to overlap the thatch on both sides until a 4-ft. long section has been covered to the required thickness. This is secured with either one or two scallops and staples (or twine) at each wing. The ridge is completed in sections in this manner, and the edges are then cut and trimmed with shears or a long-handled knife. Sometimes additional withies are arranged diagonally to pattern from wing to wing and attached to the horizontal scallops. If a chimney stack intercepts a ridge, it is usual to begin at each side of it and work towards the hips or gables. As a precaution against fire, chimney stacks should be constructed of walls which are at least 9-in. thick.

Scallops, as described in the preceding column, are provided at hips at about 2-ft. apart and bent to form a sweep. The thickness of thatch is increased at valleys in order to give a swept appearance.

# HOMEWORK PROGRAMME

THIS programme continues and completes that begun on p. 129, Vol. II.

Joinery details should be drawn preferably to full size. This is possible in most cases if the details are broken. Finished sizes and not nominal sizes should be indicated, the usual allowance for *each* dressed surface being $\frac{1}{16}$-in. and $\frac{1}{32}$-in. for planing and sandpapering respectively (see p. 97, Vol. I).

| Sheet Number. Number of Lectures per Session. | | | | Subject of Drawing. | Reading (Pages). |
|---|---|---|---|---|---|
| 24 | 25 | 26 | 27 | | |
| 13 | 13 | 13 | 14 | FLOORS.—(*a*) Draw quarter full-size details A, B and C, Fig. 8, and portions of sections at B and C, Fig. 9 sufficient to show the application of floor clips. (*b*) Sketch details at H, J, K and L, Fig. 10. | 1-6, 31-41. |
| | 14 | 14 | 15 | PARTITION.—Draw $\frac{1}{2}$-in. elevation A and quarter full-size details at B, C, D, E, F, J and K, Fig. 11. | 7-14, 42-48. |
| 14[1] | 15 | 15 | 16 | SOUND-PROOFING.—Draw $1\frac{1}{2}$-in. details at K, P, Q, S, U, W and X, Fig. 14. | 14-17, 48-51. |
| 15 | 16 | 16 | 17 | DOUBLE ROOF.—Draw $\frac{3}{8}$-in. elevation A and $\frac{3}{4}$-in. details at D, E and F, Fig. 15. | 51-56. |
| 16 | 17 | 17 | 18 | TEMPORARY TIMBERING.—(*a*) Draw, to $\frac{3}{4}$-in. scale, cross and part longitudinal sections through a 4-ft. wide and 10-ft. deep trench; assume 3-ft. depth of hard ground overlying a 3-ft. thick stratum of loamy soil, below which the soil is loose; show the application of middling and tucking boards (see Fig. 19). (*b*) Draw to 1-in. scale, centre J and K, Fig. 20. | 17-19, 56-62. |
| 17 | 18 | 18 | 19 | DOOR.—Draw: (*a*) $\frac{3}{4}$-in. elevation A and plan C, Fig. 21; (*b*) full-size details at K, L, M and P, Fig. 21 and R, Fig. 22. *OR* (*a*) Draw $\frac{3}{4}$-in. elevation A, section B and plan C, Fig. 23, together with full-size details at G and H. (*b*) Sketch the hammer-headed key joint at F, Fig. 23. | 19-24, 63-66. |
| 18 | 19 | 19 | 20 | DOORS.—Draw: (*a*) $\frac{1}{2}$-in. elevation C and full-size details at N and P (showing a 4-in. by $1\frac{3}{4}$-in. stile), Fig. 24; (*b*) $\frac{1}{2}$-in. elevation A and full-size details at F and H, Fig. 25. | 24-27, 66-70 |
| 19 | 20 | 20 | 21 | METAL WINDOW.—Draw 1-in. elevation E, section D and plan F, Fig. 28, together with full-size details at N (excluding handle), O, P and Q. | 27-31, 70-78. |
| 20 | 21 | 21 | 22 | STRAIGHT FLIGHT STAIR.—Draw $\frac{3}{4}$-in. plan D and section C, Fig. 30, together with full-size details at F, G and H. | 78-87. |
| 21 | 22 | 22 | 23 | DOG-LEG STAIR.—Draw: (*a*) $\frac{1}{2}$-in. plan D and section C, Fig. 32, amended to include the solid balustrade shown in Fig. 35; (*b*) full-size details at H, J, D and F, Fig. 35, and either detail at E, Fig. 35, or at F (including margin fillets), Fig. 32. | 87-97 (or 93). |
| | | | 24 | OPEN WELL STAIR.—Draw: (*a*) $\frac{1}{2}$-in. plan E and section C, Fig. 36; (*b*) half full-size details at J and M, Fig. 36, and at E and G, Fig. 34. | 93-97. |
| 22 | 23 | 23 | 25 | PLAIN TILING.—(*a*) Draw quarter full-size details at A and C, Fig. 41. (*b*) Sketch details at A, J and O, Fig. 42. | 97-110. |
| 23 | 24 | 24 | 26 | PANTILING, SPANISH TILING AND ASBESTOS-CEMENT SHEETING.—Draw quarter full-size details at F (right side) and L, Fig. 44, H, Fig. 45, T, Fig. 46, and M and N, Fig. 47. | 110-124. |
| 24 | 25 | 25 | 27 | COPPER AND ZINC ROOFING.[2]—Draw full-size details A, B, C, D, M, O and P, Fig. 50. | 124-134. |
| | | 26 | 28[3] | VERTICAL TILING.—Draw: (*a*) To a scale of 8-ft. to 1-in., elevation A, Fig. 43; (*b*) quarter full-size details at L, M and Q (showing reversed under eaves course), Fig. 43; (*c*) $1\frac{1}{2}$-in. details at H, K, O, P and S, Fig. 43. | 110-112. |

[1] Additional reading, pp. 7-14 and 42-48.
[2] In lieu of this, preference may be given to a sheet on windows concerned with either Fig. 26 or Fig. 27.
[3] If length of session permits.

# GENERAL SYLLABUS IN BUILDING CONSTRUCTION STAGE TWO[1]

BRICKWORK.—Extended description of the manufacture and characteristics of bricks, cements and limes ; lime and cement mortars ; concrete. Squint quoins and junctions, and rebated and splayed jambs in English and Flemish bonds ; piers ; cavity walls ; circular work ; reinforced brickwork ; raking bonds ; garden, cross, Dutch, brick-on-edge and facing bonds ; recessed, elliptical, pointed and rere arches. Damp proofing of basements ; dry areas. Stepped foundations. Concrete floor construction. Decorated brickwork. Fireplaces, flues, chimney breasts and stacks ; bye-laws. Setting out. *See Chapter One, Vol. II.*

DRAINAGE.—Characteristics and brief description of the manufacture of drain pipes, including bends, junctions, channels and taper pipes, gullies and interceptors. Setting out and construction of drains. Drainage systems for small buildings ; inspection, interception and ventilation. *See Chapter Two, Vol. II.*

MASONRY.—Formation and classification of stones ; characteristics, tests. Quarrying, mining and machine dressing. Stone dressings to door and window openings. Cornices. Stone steps and stairs. *See Chapter Three, Vol. II.*

MILD STEEL ROOF TRUSSES.—Mild steel roof trusses up to 40-ft. span, with alternative details. *See Chapter Four, Vol. II.*

CARPENTRY.—Extended description of the classification, structure, conversion, seasoning, preservation, defects, characteristics and uses of timbers ; preparation of timber and machines employed. Double and framed floors ; determination of sizes of joists ; floor finishes, including boards, blocks, plywood, parquet, cork and rubber. Stoothed, trussed, terra-cotta, concrete, plaster, asbestos-cement and glass partitions. Sound-proofing. Double and queen post roofs ; laminated trusses. Timbering of deep trenches and centres up to 10-ft. span. *See Chapter One, Vol. III.*

JOINERY.—Doors, including fanlights, semicircular headed, glazed and flush. Windows, including semicircular headed boxed frame with sliding sashes, boxed frame with three lights, and metal. Stairs ; terms ; types ; essential requirements ; step proportions ; construction and detailing of straight flight, dog-leg and open well stairs ; open and solid balustrades ; winders ; special steps. Manufacture, characteristics and uses of plywood, laminboards, blockboards, battenboards and composite boards. *See Chapter Two, Vol. III.*

ROOF COVERINGS.—Manufacture and characteristics of clay and shale plain tiles, pantiles, Italian, Spanish and interlocking tiles ; eaves, ridge, hip, valley and verge details ; vertical tiling. Concrete tiles, asbestos-cement tiles and corrugated sheets, corrugated iron sheets. Stone slating. Shingles. Copper and zinc details. *See Chapter Three, Vol. III.*

[1] This syllabus appears in parts as chapter headings in Vols. II and III.

# INDEX


A

Abrasive paper, 30
Abutments, 116, 120, 126, 129
Accelerator, 120
Accra mahogany, 5, 21, 70, 100
Acoustic floor clips, 38
Adhesives, 101, 103
  animal glue, 101, 102
  blood albumen glue, 101
  casein glue, 101, 103
  oil seed residue glue, 101
  resin cements, 101-103
  Scotch glue, 101
  soya bean glue, 101
  vegetable glue, 101
Aerated cement, 47
African ebony, 20
  mahogany, 5, 21, 70, 100
  olive, 23
  teak, 21, 38
  walnut, 24
Air bricks, 15
Alder, 70
Aluminium, 47, 102
American ash, 19, 70
  beech, 19, 38, 56, 70, 98
  birch, 20, 36
  black walnut, 24
  chestnut, 20
  lime, 19
  red oak, 22, 38
  white oak, 22, 38
  whitewood, 24
Ammonium phosphate, 14
Andaman padauk, 5, 23
Angles, steel, 34
  cleats, 36
Angle tiles, 111
Angular hips, 109
  valleys, 110
Animal glue, 101, 102
Annual rings, 1, 4, 5, 17-24, 126
*Anobium punctatum*, 16
Antique glass, 66
Apex stones, 126
Apitong, 21, 38
Appayia, 19, 98
Aprons, lead, 112
  stair, 78, 80, 88
Architraves, 63, 66, 68, 70, 93
Artificial seasoning, 9-12, 38, 100
Asbestos, 121
  cement, 47, 51, 53, 54, 103, 120-124
    characteristics, 121, 124
    details, roofing, 121-124
    manufacture, 121
    partitions, 47, 48
    sheets, 48, 51, 53, 54, 103, 122-124
    slates, 121, 122
    tiling, 53, 122
    " Turnall " Trafford tiles, 122
Ash, 2, 17, 19, 23, 38, 40, 70
Ashlaring, 52
Asphalt asbestos felt, 124
Assembling plywood boards, 100
Auger, 29, 104
Australian blackwood, 5, 20
  walnut, 24, 102
Austrian oak, 22
Automatic cutter grinder, 31
  feeding table, 28, 29
  saw sharpening machine, 30, 31
Avodiré, 19, 98

B

Balancing steps, 78, 80, 82
Balsa, 19
Balsam fir, 1
Baltic redwood, 1, 2, 5, 18, 36, 38, 106, 110, 111
  whitewood, 1, 19, 38
Balusters, 30, 78, 88, 90, 93, 95, 97
Balustrades, 78, 80, 88, 90, 93, 95, 97, 102
  open, 78, 80, 88, 90, 93, 95, 97
  solid, 78, 80, 90, 93, 95, 102
Band re-sawing machine, 6
  saw, 6, 26, 28, 31
  sawing machine, 27, 28, 97, 100
Banisters, 78, 80, 88, 90, 93, 95, 97, 102
Banksian pine, 18
Barefaced tenon joint, 88, 90
Bark, 2, 40, 41, 98
Barking lathe, 98
Bars, steel, 36, 43, 45, 47, 48, 52, 84
Basilican tiling, 116-118
Basis price, copper, 130
Basketweave pattern, 38
Basswood, 19
Bast, 2
Bats, clay, 104
Battenboards, 103
Battens, 5, 6, 54, 106, 109, 110, 111, 114, 116, 118, 120, 121, 125, 126, 129
Baulks, 5, 6, 8, 24
Baywood, 5, 21, 70, 98
Beaded drips, 133
Beading, 28, 63, 66, 68
  head, 28
  rod, 133
Beams, 31, 32, 34-36, 52, 62
  filler, 36
  flitched, 31
  sizes, 32, 34, 35
  steel, 31, 32, 34-36, 52
  straining, 43
Bearers, 38, 52, 78, 80, 87, 88, 90, 93, 96, 130
Bed, thatch, 133, 134
Beech, 1, 2, 4, 5, 19, 38, 56, 70, 98
Belt sander, 30
Bending moments, 32, 34
  wood, 63, 72, 97
Benin mahogany, 5, 21, 70, 100
  walnut, 24
Bethel preserving process, 12, 13
Bevel cutting, 28
  housed joint, 56
Bevelled saw, 26
Bevelling, 28, 30, 49, 58, 70
Bevels, saw, 26, 30
Bifurcated stairs, 79
Binders, 31, 32, 34-36, 45
  sizes, 32, 34, 35
Birch, 1, 4, 5, 19, 20, 36, 38, 40, 70, 98, 102
  American, 20, 36
  black, 20, 36
  Canadian yellow, 20, 36
  curly, 20, 36
  European, 19, 98
  Quebec, 20, 36
  yellow, 20, 36
Bird's-eye figure, 5, 22
  maple, 5, 22, 38, 40, 101
Birdsmouthed joint, 52, 83, 88
Black bean, 5, 19, 70, 100
  birch, 20, 36
  guarea, 20
Black—contd.
  Sea walnut, 24
  walnut, American, 24
Blende, 132
Blister figure, 5, 18, 21-23
  maple, 5, 22, 38, 40, 101
Blisters, saw, 27
Blockboards, 70, 103
Blocks, built-up, 96, 97
  stair, 78, 83, 87
Blood albumen glue, 101
Blow-lamp, 15
Blue vitriol, 12, 13, 16
Blythe's preserving process, 13
Boarding, roof, 106, 109, 110, 114, 118, 126, 130, 132
Boards, 5, 6, 10, 29, 32, 34, 36, 38, 40, 41, 45, 49, 84
Bolection mouldings, 63, 68
Boles, 5, 6, 98
Bolts, 36, 52, 56, 66, 72
Bombay blackwood, 23
Bonding strips, 43
Bonnet hip tiles, 109
Booms, 52
Bordered pits, 2
Boring machine, 29
Botanical classification, timber, 1
Bottomer, 127
Boucherie preserving process, 13
Bowing, 8
Box, 2
Braces, 43, 52, 53, 60
Brackets, 78, 83, 87
Brashness, 8
Brick-nogged partition, 43
Brick-on-edge coping, 116
Brickwork, reinforced, 43, 45
Bridging joists, 31, 32, 34, 35
Bridle joint, 43, 52
British Columbia pine, 2, 5, 17, 36, 40, 56, 70, 98, 101
  Honduras cedar, 20
  pitch pine, 18, 38
Brittleness, 4, 8
Bronze, 103
  partitions, 48
Brown oak, 22
Brush application, preservatives, 14

Building paper, 40, 130
Bulk excavation, 58
Bull Dog floor clips, 38
Bull-nosed steps, 80, 93, 96
Bull's-eye arch centering, 60
Burls, 5, 98
Burma padauk, 23
Burnettizing preserving process, 13
Burning tiles, 105
Burr figure, 5, 19, 24
Burrs, 5, 98
Butt joints, 36, 58, 93, 130
Butt preserving treatment, 13

C

Cabot's quilt, 49
Calamine, 132
Camber, tiles, 104, 105, 109, 110, 111, 120
Cambium, 2, 4
Canada balsam, 4
Canadian red pine, 18, 71
  spruce, 1, 18
  white pine, 1, 2, 5, 18
  yellow birch, 20, 36
    pine, 1, 2, 5, 18
Canary whitewood, 24
Cape Lopez mahogany, 5, 21, 70, 100
Capillary grooves, 66
Cappings, copper, 130
  moulded, 78, 88, 93
  zinc, 133
Caps, newel, 30, 78, 79, 88, 93, 95
Carbolizing preserving process, 13
Carpets, 41
Carriage-pieces, 78, 80, 83, 87, 88, 93, 96
Carriages, 78, 80, 83, 87, 88, 93, 96
Case-hardening, 8, 10
Casein glue, 101, 103,
Casements, metal, 74, 76, 78, 93
  fastener, 76
  stays, 66, 76
Casings, 36, 68
Cauls, 63, 100, 101
Cavity walls, 34, 45, 49, 106, 111, 116
Cedar, 17, 20, 126
  Central American, 20
  Pacific red, 17, 126
  western red, 17, 126
Ceiling joists, 31, 32, 34, 35, 42, 43, 49, 52, 54, 56, 111
Cellactite, 124
Cellar fungus, 16
Cells, 1, 2, 4, 7
Cellulose flooring, 41
Celotex, 49
Cementing plywood, 100, 101
Centering, 60-62
  circular arch, 60
Centering—contd.
  pointed arches, 60
  semicircular arches, 60
    elliptical arch, 62
Central American cedar, 20
  mahogany, 5, 21, 70, 98
Chain cutter, 29
Chamfered joint, 93
Chamfering, 28, 30, 43
Characteristics, tiles, 105
  timber, 17-24
Checking, 8, 10, 100
  case-hardening, 8, 10
  end, 8
  honeycomb, 8
  internal, 8
  surface, 8
  through, 8
Cherry mahogany, 22
Chipbreaker, 29, 30
Cigar-box cedar, 20
Circassian walnut, 24
Circle valleys, 109, 110, 126
Circular arch centering, 60
  saw bench, 24-27, 97
  saw mill, 6
  saws, 6, 24-27, 30, 31, 97, 100
    bevelled, 26
    cross-cut, 24, 26
    drunken, 30
    ground-off, 26
    hollow-ground, 26
    plate, 6, 24-27, 30, 31, 97, 100
    rip, 24, 26, 30
    swage, 26
      gulleting, 30
      setting, 26
      sharpening, 30, 31
      tensioning, 27
  stairs, 79
Clamping plywood boards, 101
Classification, timber, 1, 17-24
  botanical, 1
  commercial, 1, 17-24
    hardwoods, 17, 19-24
    softwoods, 17-19
Clay, 56, 104
  block and brick partitions, 45
Cleats, 36, 45, 52-54, 56, 57
Cleft shingles, 126
Clipper, plywood, 100
Clips, copper, 130
  floor, 38
  zinc, 132, 133
Cloakroom, 93
Close strings, 80, 83, 84, 87, 88, 90, 93, 96
Clots, clay, 104
Coal-tar, 12
Coarse grain, 5, 19
  texture, 5, 21, 23
Cogged joints, 31, 35, 43
Coke-breeze bricks, 110, 111
  concrete block partitions, 45-47, 90, 93
Cold steeping preserving process, 14
Collapse, 8
Collars, roof, 52
Columbian pine, 2, 5, 17, 36, 40, 56, 70, 98, 101
Combed joint, 70
Comb grain, 4-7, 22, 38, 100, 126
Combined air and kiln seasoning, 11, 12
  log and deal frame, 6
Commercial classification, timber, 1, 17-24
Commode steps, 78, 80
Common furniture beetle, 16
  partitions, 42, 43
Compo, 114
Composite-boards, 103
Compression stress, 32, 56, 62
Concrete, 36, 38, 41, 45-47, 90, 93, 120
  blocks, 36
    partitions, 45-47, 90, 93
  lightweight, 45-47
  reinforced, 36, 49
  sawdust, 47
  screeding, 38
  sub-floors, 38, 41
  test, dryness, 38
  tiles, 120
    moulding machine, 120
Cone hip tiles, 109, 116, 120
Conical roll, 130
*Coniferæ*, 1
*Coniophora cerebella*, 16
Construction, steps, 83, 84, 87, 97
Continuous guides, 58
  stair, 79, 80
Conversion, timber, 4-6, 98, 100
  flat-sawn, 4, 5, 7, 24, 126
  plain-sawn, 4, 5, 7, 24, 126
  quarter-sawn, 4-7, 22, 38, 100, 126
  rift-sawn, 4-7, 22, 38, 100, 126
  rotary-cutting, 98, 100
    half-round cutting, 98
    stay-log cutting, 98
  slicing, 98, 100
Copings, 116, 126
Copper roofing, 129-132
  cappings, 130
  characteristics, 129, 130
  clips, 130
  drips, 132
  flashings, 132
  hips, 132
  joints, 130-132
    standing seams, 130, 132
    welts, 130, 132
    wood rolls, 130, 132
  manufacture, sheets, 129
    sizes, 130
Copper—contd.
  ridges, 132
  strings, 130
  valleys, 132
Copper sulphate, 12, 13
Corbel, 112
Cores, plywood, 98, 100, 103
Cork floor covering, 40, 41
  carpet, 41
  manufacture, 40
  skirtings, 40
  tiles, 40
Corrosive sublimate, 12, 14, 16
Corrugated metal saw-edge fasteners, 70
  sheets, 122, 124
    " Everite Bigsix," 122, 124
    standard, 124
Cotswold stone slating, 124-126
Counter-battens, 106, 114, 126
  laths, 31, 34, 36, 43
Cover beads, 74
  fillets, 78, 88
Cradle, 87
Cradling, 34, 36, 52
Creasing, tile, 110, 116, 120
Creosote, 12-14, 16, 38
Creosoting, 12-14, 16, 38, 110
Cross bandings, 70, 98, 100
  cut saw, 24, 26
  cutting timber, 24, 26, 30
  grain, 97, 98, 100, 102
  tongued joint, 70, 72, 96
Crotch, 5, 24, 98
Crushing rolls, 104
Cuban mahogany, 5, 21, 70, 98
  pine, 18, 38
Cubical rot, 15
Cupboard, 84
Cupping, 8, 40
Curing chamber, 120
Curly birch, 20, 36
  grain, 4, 5, 20
  maple, 5, 22, 38, 40, 101
Curtail step, 80, 97
Curved soffit linings, 70, 72
Cussomes, 125
Cut and mitred hips, 109, 126, 129
  valleys, 110
Cut strings, 80, 97
Cutterblocks, 28-31, 100
Cutters, 28-31, 87
Cutting table, 104
Cylinder, veneering, 72
  sander, 30
Cypress shingles, 126

D

Dado panelling, 93
Damp proof courses, 15, 16

Dancing steps, 78, 80, 82
Deals, 5, 24
Death-watch beetle, 16
Deciduous, 1
Deep-cutting, 24
Defects, timber, 4, 7, 8, 10, 14-17, 38, 40, 41, 51, 100, 103, 130
  brashness, 8
  brittleness, 4, 8
  cellar fungus, 16
  checking, 8, 10, 100
    case-hardening, 8, 10
    end, 8
    honeycomb, 8
    internal, 8
    surface, 8
    through, 8
  collapse, 8
  common furniture beetle, 16
  cupping, 8, 40
  death-watch beetle, 16
  dry rot, 7, 14-16, 38, 41, 51
  Iyctus powder-post beetle, 16, 17
  shakes, 8. 20
  shrinkage, 7, 8, 40, 102, 126
  splitting, 8, 10, 102, 126
  swelling, 7, 40
  warping, 8, 10, 40, 102, 103, 130
    bow, 8
    cup, 8, 40
    spring, 8
    twist, 8, 102
    wind, 8
Diagonal grain, 4
Diamond slates, 121, 122
Diatomaceous earth, 45
*Dicotyledoneæ*, 1
Diffuse-porous woods, 2, 4, 19, 20, 21
Dihedral angle, 109, 110
Diminished fliers, 80
  stile door, 68
Dipping preserving process, 14
Disc rivets, 121, 122
  and bobbin sander, 30
  sander, 30
Disposition, timber, 1, 17-24
Distributing bars, 36
Dog-leg stairs, 78, 79, 87-93
Door casings, 43, 45
  posts, 42, 45
Doors, 42, 43, 45, 47, 51, 63-70, 84, 93
  fanlight, 63-66
  fire-resisting, 70
  flush, 68, 70, 93
  glazed, 66, 68, 70
  semicircular headed, 66, 70
Dormer window, 52
Double boarded floors, 36, 38
  dimension saw bench, 30
  eaves course, 105, 106, 110, 121, 129
Double—contd.
  floors, 31-34
  half-turn stairs, 79
  lock cross welt, 130
  quarter-turn stairs, 79
  Roman tiling, 118
  roofs, 51, 52
  spindle moulder, 29
  tenoned joint, 63, 68, 70
Douglas fir, 2, 5, 17, 36, 40, 56, 70, 98, 101
Dovetail halved joint, 52
  housed joint, 52, 88
Dovetailing, 29, 30, 70, 97
Dowelled joints, 66, 72, 88
Drains, 15, 56-58
Draught bead, 72
  excluder, 51
  slip, 68
  strips, 51
Draw-pinned joints, 88
Drips, copper, 132
  zinc, 133
Driving screws, 122, 124
  wedges, 57
Drops, newel, 30, 78, 79, 88, 93, 95
Drum sander, 30
Drunken saw, 30
Dry and wet bulb thermometer, 10, 11
Dry-cemented process, 100
Drying tiles, 105
Dry rot, 7, 14-16, 38, 41, 51
Duala mahogany, 5, 21, 70, 100
Durmast oak, 22
Dutch elm, 20

E

Easing, 78, 87, 96
East African olive, 23
  Indian satinwood, 5, 23, 98
    walnut, 21
Eaves, 53, 54, 105, 106, 110, 112, 114, 118, 121, 122, 124, 125, 129, 134
  filler piece, 124
  under tiles, 105, 106, 110, 114, 118, 121
Ebony, 20
  African, 20
  Macassar, 20
Edge grain, 4-7, 22, 38, 100, 126
  runner, 104
Edging slips, door, 68
  timber, 24
Eel-grass, 49
Electrical moisture meters, 11
Elliptical stairs, 79
Elm, 2, 5, 17, 20, 126
Emery discs, 31
Empty-cell preserving process, 13
End checking, 8
  grain, 4
Eng, 20
English ash, 19, 70
  elm, 20, 126
  oak, 22, 38, 40, 70, 126
  walnut, 24
Essential requirements, stairs, 80, 82-84
European birch, 19, 98
  larch, 1, 17, 56
  spruce, 1, 19, 38
  walnut, 24
Even grain, 4
  texture, 5, 18, 20-23
Evergreen timbers, 1, 40
"Everite Bigsix" corrugated sheets, 122, 124
Expanded metal, 36, 47, 122
Exposure line, shingles, 129
Extension hinges, 74, 76
External fan compartment kiln, 10

F

Face plies, 98, 100
Fanlights, 63-66
Fascias, 53, 78, 88, 106, 120
Feather curl figure, 5
  edged boarding, 109
  tongues, 72
Feeding table, 28, 29
Felling timber, 5
Felt, 40, 49, 51, 106, 109, 111, 116, 118, 124, 126, 130
  paper, 40
Fences, 24, 28-30
Fibres, 4
Fibre saturation point, 7
Fibrous wood cement, 47
Fiddle-back figure, 5, 20-23
  maple, 5, 22, 38, 40, 101
Figure, 4, 5, 17-24
  bird's-eye, 5, 22
  blister, 5, 18, 21-23
  burr, 5, 19, 24
  feather curl, 5
  fiddle-back, 5, 20-23
  mottled, 5, 17, 19, 20, 22, 23
  pith flecks, 5, 19, 24
  ram's horn, 5
  ribbon, 5, 21-24
  ripple marks, 5, 21, 23
  roe, 5, 21, 23
  silver grain, 4, 5, 22
  stripe, 5, 21, 23, 24
Filler beams, 36
Fillets, mortar, 111, 114, 116, 126
  wood, 31, 36, 42, 43, 56, 57
Fine texture, 5, 19, 20
Finger cone pine, 18
Finishes, floor, 36-41
Finishing plywood boards, 102
Fireclay blocks, 36
Fire-retarding timber, 14, 126
Firring, 34, 36
Firs, 1
Fish plate, 56
Five-cutter, 28
Fixed cutters, 28
Fixing bricks, 110
Flashings, copper, 132
  lead, 116, 120, 129
  zinc, 133
Flat cut, 98
  grain, 4, 5, 7, 24, 126
  sawn timber, 4, 5, 7, 24, 126
Flecks, 5, 19, 24
Fliers, 78, 80, 83, 84, 87, 90, 93
Flight, stair, 78
Flitched beams, 31
Flitches, 5, 6, 98
Floating floor, 49
Floor bearers, 38
  binders, 31, 32, 34-36, 45
    determination of sizes, 32, 34, 35
  boards, 29, 32, 34-36, 38, 40, 41, 49, 84
  clips, 38
  filler beams, 36
  finishes, 36-41
    carpet, 41
    cellulose, 41
    cork, 40, 41
      carpet, 41
      tiles, 40
    linoleum, 41
    parquet, 40
      inlaid, 40
      ordinary, 40
      plated, 40
    plywood, 40, 41, 102
    rubber, 41
      sheet, 41
      tiles, 41
    strip, 36
    wood blocks, 38, 40
      boards, 36, 38
  girders, mild steel, 34, 35
    determination of sizes, 34, 35
  joists, 31, 32, 34, 35, 40, 42, 43, 52, 83, 88, 90
    determination of sizes, 32, 34
Floors, 31-43, 45, 48-51
  double, 31-34
    boarded, 36, 38
  fire-resisting, 36
  floating, 49
  framed, 34-36
  sound proofed, 48-51
  triple, 34-36
Flowered satinwood, 5, 23, 98
Flush doors, 68, 70, 93
  fire-resisting, 70
Flushing cisterns, 49, 93

Foamed cement, 47
Folding wedges, 56, 57, 60
Followers, 125
Forced draught kilns, 10-12
Form, plywood, 102
Four-cutter planing and thicknessing machine, 28
Framed floors, 34-36
  partitions, 43-45
Frames, trench, 57, 58
Freezing test, tiles, 105
French walnut, 24
Fruit bodies, 14-16
Full-cell preserving process, 12, 13
Fungi, 12, 14

G

Gaboon, 20, 70, 98
  mahogany, 20, 70, 98
Galleting, 114, 116, 118
Galvanized corrugated iron sheets, 124
Gauge, asbestos-cement slating, 121
  pantiling, 114
  plain tiling, 106, 109, 114
  Roman tiling, 118
  shingles, 129
  Spanish tiling, 118
  stone slating, 125
  vertical tiling, 110
Genera, timbers, 1
General joiner, 30
Geometrical stairs, 79
Gilding metal, 103
Girders, mild steel, 34, 35
  determination of sizes, 34, 35
Glass brick partitions, 48
  paper, 30
Glazed doors, 66, 68, 70
Glazing, 63, 66, 76
  bars, 63, 66, 74
  beads, 63, 66, 68
Glue blocks, 78, 83, 87
  spreader, 100
Glues, 101, 102
Gluing, 66, 70, 72, 87, 97, 98, 100-103
Going, 78, 79, 82, 84, 93, 95
Graded timber, 31, 32, 35
Grain, 4, 5, 17-24
  coarse, 5, 19
  comb, 4-7, 22, 38, 100, 126
  cross, 97, 98, 100, 102
  curly, 4, 5, 20
  diagonal, 4
  edge, 4-7, 22, 38, 100, 126
  end, 4
  even, 4
  fine, 5
  flat, 4, 5, 7, 24, 126
Grain—contd.
  interlocking, 4, 5, 17, 19-24
  irregular, 4, 5, 19-22
  quarter, 4-7, 22, 38, 100, 126
  short, 4
  silver, 4, 5, 22
  slash, 4, 5, 17, 24, 126
  spiral, 4, 17, 18
  straight, 4, 5, 17-24, 126
  uneven, 4
  vertical, 4-7, 22, 38, 100, 126
  wavy, 4, 5, 17, 20-24
Granny bonnet hip tiles, 109
Granulated cork, 48, 51, 70
Great maple, 5, 23, 70, 98, 101
Greenheart, 20
Grey fir, 17, 38
Greywood, Indian silver, 20, 70, 98
Grinding machine, 30
  wheel, 30
Grindstone, 31
Grips, 58
Grooving, 28-30
  head, 29
Ground-off saw, 26
Growth rings, 1, 4, 5, 17-24, 126
Guarea, 20
  black, 20
  scented, 20
  white, 20
Guillotine, 100
Gulleting, saw blades, 30
Gullet, saw, 24
Gum, 2, 21
Gun-stock stiles, 68
Gurjun, 21, 38
Gutters, 106, 110, 116, 118, 132

H

Hair felt, 40, 49, 51
Half-newel, 88
  round hip tiles, 109, 116
    ridge tiles, 109, 112, 126
  space landings, 79, 80, 88, 90, 93
  turn stairs, 79, 80, 82-95
Hammer-headed key tenoned joint, 66, 70
Hand-moulded tiles, 104-106, 110, 112, 116
Handrail punch, 72
  screw bolts, 66, 72
Handrails, 78, 84, 87, 88, 95
Hand trenching, 84
Hangers, 52
Hard maple, 5, 22, 38, 40, 101
Hardwoods, 1-5, 19-24
  characteristics and uses, 19-24
  classification, 17, 19-24
    Accra mahogany, 5, 21, 70, 100
Hardwoods—contd.
  classification—contd.
    African ebony, 20
      mahogany, 5, 21, 70, 100
      olive, 23
      teak, 21
      walnut, 24
    alder, 70
    American ash, 19, 70
      beech, 19, 38, 56, 70, 98
      birch, 20, 36
      black walnut, 24
      chestnut, 20
      lime, 19
      red oak, 22, 38
      white oak, 22, 38
      whitewood, 24
    Andaman padauk, 5, 23
    apitong, 21, 38
    appayia, 19, 98
    ash, 2, 17, 19, 23, 38, 40, 70
      American, 19
      English, 19, 70
      Japanese, 19
      mountain, 23, 38
    Australian blackwood, 5, 20
      walnut, 24, 102
    Austrian oak, 22
    avodiré, 19, 98
    balsa, 19
    basswood, 19
    baywood, 5, 21, 70, 98
    beech, 1, 2, 4, 5, 19, 38, 56, 70, 98
      American, 19, 38, 56, 70, 98
      Southland, 19
    Benin mahogany, 5, 21, 70, 100
      walnut, 24
    birch, 1, 4, 5, 19, 20, 36, 38, 40, 70, 98, 102
      American, 20, 36
      black, 20, 36
      Canadian yellow, 20, 36
      curly, 20, 36
      European, 19, 98
      Quebec, 20, 36
      yellow, 20, 36
    bird's-eye maple, 5, 22, 38, 40
    black bean, 5, 19, 70, 100
      birch, 20, 36
      guarea, 20
      Sea walnut, 24
      walnut, American, 24
    blackwood, Australian, 5, 20
      Bombay, 23
    blister maple, 5, 22, 38, 40
    Bombay blackwood, 23
    British Honduras cedar, 20
    brown oak, 22
    Burma padauk, 23
    Canadian yellow birch, 20, 36
Hardwoods—contd.
  classification—contd.
    canary whitewood, 24
    Cape Lopez mahogany, 5, 21, 70, 100
    cedar, British Honduras, 20
      Central American, 20
      cigar-box, 20
      Mexican, 20
      Nicaraguan, 20
      Trinidad, 20
      West Indian, 20
    Central American cedar, 20
      mahogany, 5, 21, 70, 98
    cherry mahogany, 22
    chestnut, American, 20
      Spanish, 20
      sweet, 20
    chuglam, white, 20, 70, 98
    cigar-box cedar, 20
    Circassian walnut, 24
    Cuban mahogany, 5, 21, 70, 98
    curly birch, 20, 36
      maple, 5, 22, 38, 40
    Duala mahogany, 5, 21, 70, 100
    durmast oak, 22
    East African olive, 23
      Indian satinwood, 5, 23, 98
      walnut, 21
    ebony, 20
      African, 20
      Macassar, 20
    elm, 2, 5, 17, 20, 126
      Dutch, 20
      English, 20, 126
      white, 20
      wych, 20
    eng, 20
    English ash, 19, 70
      elm, 20, 126
      oak, 22, 38, 40, 70, 126
      walnut, 24
    European walnut, 24
    fiddle-back maple, 5, 22, 38, 40, 101
    flowered satinwood, 5, 23, 98
    French walnut, 24
    gaboon, 20, 70, 98
      mahogany, 20, 70, 98
    great maple, 5, 23, 70, 98, 101
    greenheart, 20
    grey fir, 17, 38
    greywood, Indian silver, 20, 70, 98
    guarea, 20
      black, 20
      scented, 20
      white, 20
    gurjun, 21, 38
    hard maple, 5, 22, 38, 40
    Honduras mahogany, 5, 21, 70, 98
      rosewood, 23
    hornbeam, 21

Hardwoods—contd.
classification—contd.
In, 20
Indian laurel, 5, 21, 70
rosewood, 23
silver greywood, 20, 70, 98
iroko, 21
Italian walnut, 24
Jamaican mahogany, 5, 21, 70, 98
satinwood, 23, 98
Japanese ash, 19
oak, 22, 38
jarrah, 21, 38
kanyin, 21, 38
karri, 21
keruing, 21, 38
kokko, 21
Lagos mahogany, 5, 21, 70, 100
lauan, red, 21
white, 21
laurel, Indian, 5, 21, 70
lignum vitæ, 21
lime, 21
American, 19
Macassar ebony, 20
mahogany, 1, 2, 5, 20, 21, 70, 98, 100
Accra, 5, 21, 70, 100
African, 5, 21, 70, 100
Benin, 5, 21, 70, 100
Cape Lopez, 5, 21, 70, 100
Central American, 5, 21, 70, 98
cherry, 22
Cuban, 5, 21, 70, 98
Duala, 5, 21, 70, 100
gaboon, 20, 70, 98
Honduras, 5, 21, 70, 98
Jamaican, 5, 21, 70, 98
Lagos, 5, 21, 70, 100
Porto Rico, 5, 21, 70, 98
sapele, 5, 23, 98
Spanish, 5, 21, 70, 98
West Indian, 5, 21, 70, 98
makoré, 22
maple, 5, 22, 23, 38, 40, 70, 98, 101
bird's-eye, 5, 22, 38, 40
blister, 5, 22, 38, 40
curly, 5, 22, 38, 40
fiddle-back, 5, 22, 38, 40
great, 5, 23, 70, 98, 101
hard, 5, 22, 38, 40
Queensland, 5, 22
rock, 5, 22, 38, 40
sugar, 5, 22, 38, 40, 101
white, 5, 22, 38, 40
meranti, red, 22
white, 22
yellow, 22
Mexican cedar, 20
mountain ash, 23, 38
mvule, 21
Hardwoods—contd.
classification—contd.
Nicaraguan cedar, 20
Nigerian walnut, 24
oak, 1, 2, 4, 5, 16, 17, 22, 23, 38, 40, 98, 101, 126
American red, 22, 38
white, 22, 38
Austrian, 22
brown, 22
durmast, 22
English, 22, 38, 40, 70, 126
Japanese, 22, 38
pedunculate, 22
Polish, 22
Russian, 22
sessile, 22
silky, 22
Tasmanian, 23, 38
Victorian, 23, 38
wainscot, 22
obeche, 23
odum, 21
okoumé, 20, 70, 98
olive, East African, 23
olon, 19, 98
padauk, Andaman, 5, 23
Burma, 23
pedunculate oak, 22
plane, 5, 23, 70, 98, 101
Polish oak, 22
Porto Rico mahogany, 5, 21, 70, 98
Pyinkado, 23, 38
Quebec birch, 20, 36
Queensland maple, 5, 22, 101
walnut, 24, 102
red lauan, 21
meranti, 22
seraya, 23, 38
Rhodesian teak, 5, 24, 38
rock maple, 5, 22, 38, 40
rosewood, Honduras, 23
Indian, 23
sapele, 5, 23, 98
mahogany, 5, 23, 98
satinwood, East Indian, 5, 23, 98
flowered, 5, 23, 98
Jamaica, 23, 98
West Indian, 23, 98
scented guarea, 20
seraya, red, 23, 38
white, 23, 38
sessile oak, 22
silkwood, 5, 22
silky oak, 22
Southland beech, 19
Spanish chestnut, 20
mahogany, 5, 21, 70, 98
sugar maple, 5, 22, 38, 40, 101
sweet chestnut, 5, 20
Hardwoods—contd.
classification—contd.
sycamore, 5, 23, 70, 98, 101
Tasmanian myrtle, 22
oak, 23, 38
teak, 5, 21, 23, 34, 38, 126
African, 21, 38
Rhodesian, 5, 24, 38
Trinidad cedar, 20
Victorian oak, 23, 38
walnut, 21, 24, 40, 70, 98, 102
African, 24
American black, 24
Australian, 24, 102
Benin, 24
Black Sea, 24
Circassian, 24
East Indian, 21
English, 24
European, 24
French, 24
Italian, 24
Nigerian, 24
Queensland, 24, 102
West Indian cedar, 20
mahogany, 5, 21, 70, 98
satinwood, 23, 98
white chuglam, 20, 70, 98
elm, 20
guarea, 20
lauan, 21
meranti, 22
seraya, 23, 38
whitewood, American, 24
canary, 24
wych elm, 20
yang, 21, 38
yellow birch, 20, 36
meranti, 22
identification, 4
sources, 1, 19, 24
structure, 2-4
Hatched tiles, 105
Headroom, stairs, 78, 80, 84, 93, 95
Headstock, 30
Heart shakes, 18, 20
Heartwood, 2
Hemlock, western, 17, 38
Herringbone pattern, 38
Hips, 106, 109, 116, 118, 126, 129, 132, 134
angular, 109
bonnet, 109
cone, 109, 116, 120
copper, 132
cut and mitred, 109, 126, 129
half-round, 109
purpose-made, 109
Hog-back ridge, 109
Holding down clips, 133
Holing tiles, 104, 120
Hollow chisel, 29-31
Hollow-ground saw, 26, 30
Homework programme, 135
Honduras mahogany, 5, 21, 70, 98
rosewood, 23
Honeycombing, 8
Honeycomb slates, 122
Hook bolts, 122, 124
saw, 24, 31
Horizontal log band mill, 6
log frame sawing machine, 6
Hornbeam, 21
Horse, 104
Hot-and-cold steeping preserving process, 13
Hot steeping preserving process, 14
Housed joint, 29, 42, 74, 83, 87, 88, 95, 96
strings, 80, 83, 84, 87, 88, 90, 93, 96
Hyphœ, 14-16

## I

Identification, timber, 4
In, 20
Independent ceiling, 49
Indian laurel, 5, 21, 70
rosewood, 23
silver greywood, 20, 70, 98
Insulating materials, 40, 48, 49, 51, 103
Insulite, 49
Interlocking grain, 4, 5, 17, 19-24
sheet piling, 60
should be, 129
tiles, 120
Internal checking, 8
Interties, 43, 45
Iroko, 21
Irregular grain, 4, 5, 19-22
Italian walnut, 24

## J

Jack pine, 18
Jamaican mahogany, 5, 21, 70, 98
satinwood, 23, 98
Japanese ash, 19
oak, 22, 38
Jarrah, 21, 38
Joinery, 63-103
Jointing, 28-30
veneers, 100
Joints; *copper*—
drips, 132
rolls, 130, 132
standing seams, 130, 132
welts, 130, 132
Joints; *timber*—
barefaced tenon, 88, 90
bevel housed, 56
birdsmouth, 52, 83, 88

Joints—contd.
bridle, 43, 52
butt, 36, 58, 93, 130
chamfered, 93
cogged, 31, 35, 43
combed, 70
cross-tongued, 70, 72, 96
double tenoned, 63, 68, 70
tongued, 74
dovetailed, 70, 97
halved, 52
housed, 52, 88
dowelled, 66, 72, 88
draw-pinned, 88
hammer-headed key tenoned, 66, 70
handrail-screw bolted, 66, 72
housed, 29, 42, 52, 74, 83, 87, 88, 95, 96
lipped mitred, 36
mitred, 36, 70, 96
mortised and tenoned, 66, 68
notched, 52, 88
oblique haunched tenoned, 88
mortised and tenoned, 52
pinned, 66, 72
rebated, 58, 97
slot and tenoned, 43
splayed, 84
scarf, 56
stub-tenoned, 42, 43, 66, 93, 95
tongued and grooved, 36, 40, 45, 47, 58, 63, 70, 72, 80, 83, 84, 87, 88, 96, 114, 130
grooved and dovetailed, 38
mitred, 36
tusk-tenoned, 88
Joints; *zinc*—
drips, 133
beaded, 133
welted, 133
rolls, 132, 133
Joists, floor, 31, 32, 34, 35, 40, 42, 43, 52, 83, 88, 90

K

Kanyin, 21, 38
Karri, 21
Kauri pine, 5, 17, 38
Keruing, 21, 38
Kicking plate, 70
Kiln drying schedules, 10, 11
seasoning, 9-12
Kilns, 10-12, 100
external fan compartment, 10
forced draught, 10-12
natural draught compartment, 11
overhead internal fan compartment, 11
progressive, 11, 100
tunnel, 11
King post roof truss, 54, 56, 62
roll, copper, 132
Kite winders, 80, 96
Kneelers, 127
Knots, 18, 19
Kokko, 21
Korean pine, 18
Kraft paper, 49
tape, 100
Kyanizing preserving process, 14

L

Laced valleys, 106, 126
Laggings, 60, 62
Lagos mahogany, 5, 21, 70, 100
Laminated wood trusses, 53, 54
Lamination, 105
Laminboards, 45, 70, 93, 95, 103
Landings, 78-80, 82-84, 88, 93
half-space, 79, 80, 88, 90, 93
quarter-space, 78, 80, 82, 93
Lap, 106, 112, 114, 118, 122, 124, 125, 129
asbestos-cement pantiling, 122
" Everite Bigsix " corrugated sheets, 122, 124
slating, 121, 122
standard corrugated sheets, 124
" Turnall " Trafford tiles, 122
pantiling, 122, 114
plain tiling, 106
Roman tiling, 118
shingles, 129
Spanish tiling, 118
stone slating, 125
Larches, 1, 17, 56
Latex, 41
Lathe, 30, 98
Laths, 31, 34, 35, 43, 52, 83, 84, 87, 88, 114, 129
Lauan, red, 21
white, 21
Laurel, Indian, 5, 21, 70
Lifts, 58
Lead aprons, 112
cupped washers, 124
flashings, 116, 120, 129
hips, 129
ridges, 109, 129
soakers, 109, 110-112, 126, 129
valley gutters, 110, 116, 129
Lightweight concrete, 45-47
Lignum vitæ, 21
Lime, 21
American, 19
Limestones, 124, 125
Line of nosings, 79, 80
Liners, timber, 45, 47, 51
Linings, timber, 45, 47, 57
window, 70, 72, 74
Linoleum, 41
Lintels, 31
Lipped mitred joint, 36
Lips, 57, 58
Lloyd board, 49
Lock blocks, 68, 70
Logs, 5, 6, 98
Long fifteens, 125
fourteens, 125
nines, 125
sixteens, 125
thirteens, 125
twelves, 125
wippets, 125
Longitudinal shrinkage, 7, 102
Loose-cut surface, plywood, 100
Lugs, 76
Lumps, saw, 27
Lyctus powder-post beetle, 16, 17
Lye-byes, 127

M

Macassar ebony, 20
Machine-moulded tiles, 104, 105
Machines, 5, 6
asbestos-cement blending, 121
forming, 121
auger, 29, 104
band re-sawing, 6
sawing, 27, 28, 97
barking lathe, 98
boring, 29
circular saw bench, 24-27, 97
saw mill, 6
clipper, 100
combined log and deal frame, 6
concrete slab moulding, 46
tile moulding, 120
crushing rolls, 104
double-dimension saw bench, 30
dovetailing, 30
edge runner, 104
general joiner, 30
glue-spreader, 100
grindstone, 31
guillotine, 100
horizontal log band mill, 6
log frame sawing, 6
veneer slicer, 98
lathe, 30
barking, 98
mitreing, 30
mortise chain cutter, 31
hollow chisel grinder, 31
mortising, 29-31
moulding, 28-30
panel planing and thicknessing, 28
peeler, 98
planing and matching, 29, 30
and moulding, 28-30
and surfacing, 28-30
portable machine planer, 40
press, cold, 101, 121
hot, 101
pug mill, 104
rack feed saw bench, 6
reciprocating cross-cut saw, 5
rotary veneer cutter, 98
router, 29
sand-papering, 30
belt, 30
cylinder, 30
disc, 30
and bobbin, 30
drum, 30
sharpening, 30, 31
automatic cutter grinder, 31
saw, 30, 31
single-dimension saw bench, 30
spindle moulder, 29
surface-planing and thicknessing, 28
taping, 100
tenoning, 29
universal woodworker, 30
vertical log band mill, 6
spindle moulding, 29, 87
veneer slicer, 98
wire-cutting table, 104
Machine trenching, 84
Magnesium silicofluoride, 12, 16
Mahogany, 1, 2, 5, 20, 21, 70, 98, 100
Accra, 5, 21, 70, 100
African, 5, 21, 70, 100
Benin, 5, 21, 70, 100
Cape Lopez, 5, 21, 70, 100
Central American, 5, 21, 70, 98
cherry, 22
Cuban, 5, 21, 70, 98
Duala, 5, 21, 70, 100
Gaboon, 20, 98
Honduras, 5, 21, 70, 98
Jamaican, 5, 21, 70, 98
Lagos, 5, 21, 70, 100
Porto Rico, 5, 21, 70, 98
sapele, 5, 23, 98
Spanish, 5, 21, 70, 98
West Indian, 5, 21, 70, 98
Makoré, 22
Manchurian pine, 18
Manufacture, aerated cement, 47
asbestos-cement, 121
blockboards, 103
concrete blocks, 48
slabs, 46
tiles, 120
copper, 129

Manufacture—contd.
cork, 40
laminboards, 103
linoleum, 41
pantiles, 112
plain tiles, 104, 105
plywood, 98-103
rubber, 41
zinc, 132
Maple, 5, 22, 23, 38, 40, 70, 98, 101
bird's-eye, 5, 22, 38, 40, 101
blister, 5, 22, 38, 40, 101
curly, 5, 22, 38, 40, 101
fiddle-back, 5, 22, 38, 40, 101
great, 5, 23, 70, 98, 101
hard, 5, 22, 38, 40, 101
Queensland, 5, 22, 101
rock, 5, 22, 38, 40, 101
sugar, 5, 22, 38, 40, 101
white, 5, 22, 38, 40, 101
Margin, 79, 109
fillets, 93
templet, 79, 84
Match-boarding, 29, 45, 52, 54
Medium texture, 5, 19
Medullary rays, 2, 4
Memel fir, 1, 2, 5, 18, 36, 38, 106, 110, 111
Meranti, red, 22
white, 22
yellow, 22
Mercuric chloride, 12, 14, 16
Merits, plywood, 102
*Merulius lacrymans*, 14-16
Metal-faced plywood, 102, 103
Metal partitions, 48
windows, 74, 76, 78, 93
Mexican cedar, 20
Microtome, 4
Middle boards, 53, 54
lamella, 2
Middling boards, 57, 58
Mild steel roof trusses, 54, 56
Mitred joint, 36, 70, 96
Mitreing, 30
machine, 30
Modulus of section, 32, 34, 35
Moisture content, 7-12, 15, 17, 36, 100, 102
determination, 10, 11
meters, 11
Moment of resistance, 32, 34, 35
Monel metal, 103
Mop-stick handrail, 78, 95
Mortar fillets, 111, 114, 116, 126
pointing, 109, 111, 112, 114, 116, 118, 120, 122, 125
waterproofed, 116
Mortised and tenoned joint, 63, 66
Mortise lock, 70
chain cutter, 31
hollow chisel grinder, 31
Mortising, 29, 30
machine, 29-31
Motorized machines, 5
Mottled figure, 5, 17, 19, 20, 22, 23
Moulded plywood, 102
Moulding, 28-30
machines, 28-30
Mouldings, 63, 66, 68
Moulds, tile, 104, 112
Mountain ash, 23, 38
pine, 18
Muffity, 125
Mullions, 74, 78
Multi-ply boards, 45, 98, 100
Mvule, 21
*Mycelium*, 14-16

N

Nails, 106, 110, 111, 114, 118, 121, 122, 125, 129, 130, 132, 133
Natural draught compartment kiln, 11
seasoning, 8, 9
New Brunswick spruce, 1, 18
Zealand kauri, 5, 17, 38
Newels, 30, 78, 79, 87, 88, 90, 93, 95, 97
caps, 30, 78, 79, 88, 93, 95
drops, 30, 78, 79, 88, 93, 95
Newel stairs, 79, 87-90, 93-97
Nibs, tile, 104, 105, 110, 112, 120
Nicaraguan cedar, 20
pine, 18, 38
Nigerian walnut, 24
Nogging pieces, 42, 43, 48
Non-graded timber, 32, 34
Non-pressure preserving processes, 13, 14
Northern pine, 1, 2, 5, 18, 36, 38, 106, 110, 111
whitewood, 1, 19, 38
Norway fir, 1, 2, 5, 18, 36, 38, 106, 110, 111
Nose bar, 98
Nosing, 79, 82, 83, 88, 90
line, 79, 84
Notch boards, 80, 97
Notched joint, 52, 88

O

Oak, 1, 2, 4, 5, 16, 17, 22, 23, 38, 40, 98, 101, 126
American, red, 22, 38
white, 22, 38
Austrian, 22
brown, 22
durmast, 22
English, 22, 38, 40, 70, 126
Japanese, 22, 38
pedunculate, 22
Polish, 22
Russian, 22
Oak—contd.
sessile, 22
silky, 22
Tasmanian, 23, 38
Victorian, 23, 38
wainscot, 22
Obeche, 23
Oblique haunched tenoned joint, 88
mortised and tenoned joint, 52
Odum, 21
Oil seed residue glue, 101
Okoumé, 20, 70, 98
Old Roman tiling, 116-118
Olon, 19, 98
Open balustrades, 78, 80, 88, 90, 93, 95, 97
lead valley gutter, 110, 129
strings, 80, 97
tank preserving processes, 13, 14
well stairs, 79, 80, 93-95
Oregon pine, 2, 5, 17, 36, 40, 56, 70, 98, 101
Ornamental copper roll, 130
Ottawa red pine, 18, 71
white pine, 1, 2, 5, 18
Overhead internal fan compartment kiln, 11
spindle moulder, 29
Over tiles, 116, 118, 120
Oziers, thatch, 133

P

Pacific red cedar, 17, 126
Packing, saw, 27
Padauk, Andaman, 5, 23
Burma, 23
Pads, insulating, 51
stone, 31, 34, 52
Pages, 57
Pallets, 104, 105, 120, 121
Panel planing and thicknessing machine, 28
Panelling, 7, 43, 78, 90, 93, 95, 102, 103
Panels, 6, 63, 66, 68, 100
Pantiles, 56, 112-116, 122
asbestos-cement, 122
manufacture, 112
sizes, 112, 122
Pantiling, 56, 112-116
abutments, 116
eaves, 114
hips, 116
ridges, 114
valleys, 116
verges, 114, 116
Parapet walls, 116, 126
Parenchyma, 2, 4
Parquetry, 40
inlaid, 40
ordinary, 40
plated, 40
Parting beads, 70, 72, 74
slips, 72, 74
Partitions, 42-51, 52, 84, 90, 93, 101
asbestos-cement, 47, 48
brick-nogged, 43
clay block and brick, 45
concrete block and slab, 45-47, 90, 93
framed, 43-45
glass brick, 48
metal, 48
plaster slab, 47, 93
sound proofed, 48-51
stoothed, 42, 43, 48, 49, 51, 52, 84, 88, 90, 93
terra-cotta block and brick, 45
trussed, 43-45
Patching plywood, 100
Patina, 129, 130
Pattern, 79, 84, 87
Pedunculate oak, 22
Peeler, 98
Pegs, 125
Pencil-rounded, 66
Permeability test, tiles, 105, 120
Phenolic resins, 101
Piers, 34, 54
Piling sticks, 8, 10, 102
timber, 8, 10, 11
Pillars, 36
Pines, 1, 2, 5, 18, 38, 56, 71, 84, 106, 110, 111
Pinned joints, 66, 72
Pitch board, 79, 84
corrugated sheets, 122, 124
edge, 84
pine, 2, 5, 18, 38, 56, 84
pockets, 100
roofs, 106, 114, 118, 121, 122, 125
stairs, 79, 87
Pitching piece, 88
Pith flecks, 5, 19, 24
Pits, 2, 4
bordered, 2
single, 2
Pivoted light, 60
Plain-sawn timber, 4, 5, 7, 24, 126
Plain tiles, 52, 104-112, 114, 120
characteristics, 105
hand-made, 104-106
manufacture, 104, 105
burning, 105
drying, 105
moulding, 104, 105
machine, 104, 105
hand, 104
preparation of clay, 104
pressed, 104, 105
sizes, 105
tests, 105, 120
freezing, 105
permeability, 105, 120
transverse, 105, 120
texture, 105

Plain tiles—contd.
tiling, 104-112
eaves, 106, 112
hips, 109
ridges, 109, 112
valleys, 109, 110
verges, 111
vertical, 110-112
angles, 111
window openings, 112
wire-cut, 104
Planceer, 79, 93
Plane, 5, 23, 70, 98, 101
Planing, 28-30, 40, 102
and matching machines, 29, 30
and moulding machines, 28-30
and surfacing machine, 28-30
Planks, 5, 6, 24, 57
Plans, houses, 82, 85, 87, 89, 93, 94
Planted mouldings, 63
Plaster, 31, 34-36, 43, 46, 47, 54, 56, 63, 78, 83, 84, 87, 88, 90, 93
slab partitions, 47, 93
Platens, 41, 101, 121
Plates, 53, 56
Plate saw, 6, 24-27, 30, 31, 97, 100
Platforms, 57
Plinth block, 66
Plugging plywood, 100
Plywood, 36, 40, 41, 45, 49, 52, 68, 70, 93, 97-103
battenboards, 103
blockboards, 70, 103
composite boards, 103
laminboards, 45, 70, 93, 95, 103
manufacture, 98-103
assembling sheets, 100
cementing, 100, 103
conversion, 98
horizontal cutting, 98
rotary cutting, 98
vertical slicing, 98, 100, 102
drying, 100
finishing, 102
planing, 102
sanding, 102
trimming, 102
gluing, 100, 103
jointing, 100
preparation of logs, 98
pressing, 101-103
cold, 101-103
hot, 101-103
re-drying, 102
repairing, 100
trimming, 100, 102
merits, 102
metal-faced, 102, 103
moulded, 102
Plywood—contd.
sizes, boards, 102, 103
uses, 102, 103
Pointed arch centres, 100
Poling boards, 56-58
Polish fir, 1, 2, 5, 18, 36, 38, 106, 110, 111
oak, 22
Pores, 2, 4, 5, 19-24
Portable machine planer, 40
Portland cement, 100, 121
Porto Rico mahogany, 5, 21, 70, 98
Powellizing preserving process, 14
Preparation, clay tiles, 104
logs, 98
timber, 24-30
Preservation, timber, 12-15
non-pressure processes, 13, 14
steeping, 13, 14
cold, 14
hot, 14
hot-and-cold, 13
Kyanizing, 14
Powellizing, 14
pressure processes, 12, 13
Bethel, 12, 13
Blythe's, 13
Boucherie, 13
Burnettizing, 13
creosoting, 12, 13
empty-cell, 13
full-cell, 12, 13
superficial, 14
brush application, 14
dipping, 14
spraying, 14
Pressed tiles, 104, 115
Pressure bar, 98
preserving processes, 12, 13
Principal rafters, 53, 56
Profile head, 28
Progressive kiln, 11, 100
Props, 56, 57
Protected metal corrugated sheets, 124
Pugging, 48
Pug mill, 104
Pulleys, 74
Pulley stiles, 70, 72, 74
Punch, 104
Puncheons, 42, 57, 58
Purlins, 52-54, 56, 122, 124
Purpose-made eaves tiles, 122
hip tiles, 109
valley tiles, 116, 122
verge tiles 116, 118, 120, 122
Putty, 63, 66, 68, 76
Pyinkado, 23, 38

Q

Quarter grain, 4-7, 22, 38, 100, 126
partitions, 42, 43, 48, 49, 51, 52, 84, 88, 90, 93
sawn timber, 4-7, 22, 38, 100, 126
space landings, 78, 80, 82, 93
turn stairs, 79
Quarters, 42
Quebec birch, 20, 36
red pine, 18, 71
spruce, 1, 18
white pine, 1, 2, 5, 18
yellow pine, 1, 2, 5, 18
Queen post roof, 54-56
posts, 54-56
Queensland kaurie, 17
maple, 5, 22, 101
walnut, 24, 102

R

Rack feed saw bench, 6
Radial hammering, 27
shrinkage, 7
Radius rods, 60
Rake, saw, 24, 31
Ram's horn figure, 5
Rat-trap bond, 111
Rays, 2, 4, 5, 19-24
Rebated joint, 58, 97
Rebating, 28, 30
Recessing, 29
machine, 29
Reciprocating cross-cut saw, 5
Red deal, 1, 2, 5, 18, 36, 38, 106, 110, 111
lauan, 21
meranti, 22
oak, American, 22, 38
pine, 18, 71
seraya, 23, 38
Re-drying plywood boards, 102
Redwood, 1, 2, 5, 18, 36, 38, 106, 110, 111
Reeds, 114, 133
Reinforced brickwork, 43, 45
concrete floors, 36, 49
glasscrete, 48
plaster partitions, 47
Rent shingles, 126
Repairing plywood veneers, 100
Re-sawing, 6
Resin, 2, 17, 18, 40, 41, 101-103
bonded plywood, 40, 101-103
cements, 101-103
ducts, 2, 4, 21
Rhodesian teak, 5, 24, 38
Ribbon figure, 5, 21-24
Ribs, 60, 62, 66
Ridge, 105, 109, 112, 115, 118, 120, 124, 125, 129, 134
Ridge—contd.
copper covered, 132
details, 109, 112, 114, 118, 120, 124, 125, 129
hog-back, 109
lead covered, 109, 129
thatched, 134
under tiles, 105, 109
V-shaped, 109, 125
Rift-sawn timber, 4-7, 22, 38, 100, 126
Rim speed saw, 24, 26, 30
Ring fences, 29
Ripping, 24, 26, 30
Ripple marks, 5, 21, 23, 28, 30
Rip saw, 24, 26, 30
Rise, 79, 84
Risers, 29, 78, 79, 82-84, 87, 90, 96, 97
Riser templet, 79, 84
Rivets, 34, 36
Riving knife, 24
Robertson protected metal sheets, 124
Rock maple, 5, 22, 38, 40
Rods, steel, 36, 43, 45, 47, 48, 52, 84
Roe figure, 5, 21, 23
Roman tiles, 116-118
tiling, 116-118
double Roman, 118
old Roman, 118
single Roman, 118
Roof boarding, 106, 109, 110, 114, 118, 126, 130, 132
coverings, 104-134
asbestos-cement corrugated sheets, 122, 124
slating, 121, 122
tiling, 122
Basilican tiling, 116-118
copper, 129-132
galvanized corrugated iron sheeting, 124
interlocking tiling, 120
Italian tiling, 116-118
pantiling, 112-116
plain tiling, 104-112
vertical, 110-112
protected metal corrugated iron sheeting, 124
Roman tiling, 116-118
shingles, 126, 129
Spanish tiling, 118-120
stone slating, 124-126
thatching, 133, 134
zinc, 132, 133
pegs, 125, 126
Roofs, 51-56
double, 51, 52
laminated wood, 53, 54
queen post, 54-56
Rosewood, 23
Rotary cutters, 28, 30
veneer cutter, 98

Rough brackets, 78, 83, 87
carriages, 78, 80, 83
cutting conversion, 98, 102, 103
Roughcast, 53
Round top roll, 130
Router, 29
Rubber floor covering, 41
manufacture, 41
sheet, 41
tiles, 41
Rueping process, 13
Run, 78, 79
Runners, 52, 58, 60
Russian oak, 22

S

Saddle boards, 129
Sample boards, 10
Sand-paper, 30
papering, 40
machines, 30
belt, 30
cylinder, 30
disc, 30
drum, 30
portable machine planer, 40
Sandstone, 124, 125
discs, 31
Sap, 2
Sapele, 5, 23, 98
mahogany, 5, 23, 98
Sapwood, 2, 17-22
Sash doors, 66, 68
opening gear, 66
Sashes, 72, 74, 76
Satinwood, East Indian, 5, 23, 98
flowered, 5, 23, 98
Jamaica, 23, 98
West Indian, 23, 98
Saw blades, 5, 6, 24-28, 30, 31, 97, 100
band, 6, 26, 28, 31, 100
circular, 6, 24-27, 30, 31, 97, 100
bevelled, 26
cross-cut, 24, 26
drunken, 30
ground-off, 26
hollow-ground, 26, 30
plate, 6, 24-27, 30, 31, 97, 100
rip, 24, 26, 30
swage, 26
setting, 26
sharpening, 30, 31
tensioning, 30
Sawdust concrete, 47
Sawing timber, 5, 6, 24, 27, 28
Sawn shingles, 126
Saw set, 26
side, 26
spring, 26
swage, 26
Scallops, thatch, 134
Scented guarea, 20
Schedules, kiln-drying, 10
Scotch glue, 101
Scotia, 79, 83, 87
board, 79, 96
Scots pine, 1, 2, 5, 18, 36, 38, 106, 110, 111
Screeding, concrete, 38
Screws, slating, 125
Scribing cutterblocks, 29
Seamers, 130
Seasoning, 7-12, 38, 100, 102
artificial, 9-12, 38, 100
period, 12, 100
combined air and kiln, 11, 12
period, 12
natural, 8, 9
period, 8, 9
Secret lead apron, 12
valley gutter, 110
Segmental-headed cased windows, 72
Semicircular arch centres, 60
headed cased window, 70, 72
doors, 66, 70
Semi-elliptical arch centre, 62
Seraya, red, 23, 38
white, 23, 38
Sessile oak, 22
Set gauge, 26
tiles, 104, 105
Setting out, stairs, 84, 87, 90
saw blades, 26
wedges, 60
Shafting, 5
Shakes, 8, 20
Shale, 104
Sheeting, 56, 58
Sheet rubber, 41
Shingles, 126, 129
details, 126, 129
abutment, 129
eaves, 129
hip, 129
ridge, 129
valley, 129
sawn, 126
split, 126
vertical, 129
Shores, 58
Short beck, 125
grain, 4
nines-sixteens, 125
Shouldering, 114, 116, 118, 122, 124
Shoulder tongues, 66
Shrinkage, 7, 8, 40, 102, 126
longitudinal, 7, 102
radial, 7
tangential, 7, 102
Siberian larch, 1, 18
pine, 1, 18
Side dresser, 26
Silkwood, 5, 22
Silky oak, 22
Silver grain, 4, 5, 22
spruce, 18
Single dimension saw bench, 30
lock cross welts, 130, 132, 133
pits, 2
Roman tiling, 118
spindle moulder, 29
Site concrete, 15
Sitka spruce, 18
Six-cutter machine, 28
Sizes of binders, girders and joists, 32, 34, 35
Skew butt hinges, 68
Skews, 127
Skids, 8, 10, 102
Skirtings, cork, 40
wood, 49, 66, 68, 70, 87, 93
Slab sawing, 48-51
Slabs, reinforced concrete, 36
Slag wool, 48-51
Slash grain, 4, 5, 17, 24, 126
pine, 18, 38
Slates, asbestos-cement, 121, 122
Slating, stone, 124-126
Slices, 5, 6
Slicing, 98, 100
Slides, glass, 4
Slope, stairs, 79, 87
Slot and tenoned joint, 43
mortising, 30
Soakers, lead, 109, 110-112, 126, 129
Soaking preserving processes, 13, 14
Sodium fluoride, 12, 16
Soffits, eaves, 106, 114, 118
stair, 79, 93
Soft tissue, 2, 4
Softwoods, 1, 2, 4, 5, 7-9, 12, 13,1 7-19, 26, 36, 38, 40, 41, 56, 70, 98, 106, 110, 111
characteristics and uses, 17-19
classification, 17-19
balsam fir, 1
Baltic redwood, 1, 2, 5, 18, 36, 38, 100, 110, 111
whitewood 1, 19, 38
Banksian pine, 18
British Columbia pine, 2, 5, 17, 36, 40, 56, 70, 98, 101
Honduras pitch pine, 18, 38
Canadian red pine, 18, 71
spruce, 1, 18
white pine, 1, 2, 5, 18
yellow pine, 1, 2, 5, 18
Softwoods—contd.
classification—contd.
Columbian pine, 2, 5, 17, 36, 40, 56, 70, 98, 101
Cuban pine, 18, 38
Douglas fir, 2, 5, 17, 36, 40, 56, 70, 98, 101
European larch, 1, 17, 56
spruce, 1, 19, 38
finger cone pine, 18
firs, 1, 2, 5, 17-19, 36, 38, 40, 56, 70, 98, 101, 105, 110, 111
grey fir, 17, 38
Jack pine, 18
kaurie pine, 5, 17, 38
Korean pine, 18
larches, 1, 17, 56
Manchurian pine, 18
Memel fir, 1, 2, 5, 18, 36, 38, 106, 110, 111
mountain pine, 18
New Brunswick spruce, 1, 18
Zealand kaurie, 5, 17, 38
Nicaraguan pine, 18, 38
northern pine, 1, 2, 5, 18, 36, 38, 106, 110, 111
whitewood, 1, 19, 38
Norway fir, 1, 2, 5, 18, 36, 38, 106, 110, 111
Oregon pine, 2, 5, 17, 36, 40, 56, 70, 98, 101
Ottawa red pine, 18, 71
white pine, 1, 2, 5, 18
Pacific red cedar, 17, 126
pines, 1, 2, 5, 18, 38, 56, 71, 84, 106, 110, 111
pitch pine, 2, 5, 18, 38, 56, 84
Polish fir, 1, 2, 5, 18, 36, 38, 106, 110, 111
Quebec red pine, 18, 71
spruce, 1, 18
white pine, 1, 2, 5, 18
yellow pine, 1, 2, 5, 18
Queensland kaurie, 17
red deal, 1, 2, 5, 18, 36, 38, 106, 110, 111
pine, 18, 71
redwood, 1, 2, 5, 18, 36, 38, 106, 110, 111
Scots fir or pine, 1, 2, 5, 18, 36, 38, 106, 110, 111
Siberian larch, 1, 18
pine, 1, 18
silver spruce, 18
sitka spruce, 18
slash pine, 18, 38
spruces, 1, 2, 18, 19
sugar pine, 18
Swedish pine, 1, 2, 5, 18, 36, 38, 106, 110, 111

Softwoods—contd.
classification—contd.
western hemlock, 17, 38
red cedar, 17, 126
white pine, 18
Weymouth pine, 1, 2, 5, 18
white deal, 1, 19, 38
fir, 1, 19, 38
pine, 1, 2, 5, 18
spruce, 1, 18
whitewood, 1, 19, 24, 38
yellow deal, 1, 2, 5, 18, 36, 38, 106, 110, 111
pine, 1, 2, 5, 18
yew, 19
identification, 4
sources, 17-19
structure, 2, 4
Sole plates, 57, 60
Solid balustrades, 78, 80, 90, 93, 95, 102
Sound-insulated door, 51, 70
Sound-proofing, 38, 43, 46, 48-51, 103
Sources, timber, 1, 17-24
Southland beech, 19
Soya bean glue, 101
Spandrel, stair, 79, 90
Spanish chestnut, 20
mahogany, 5, 21, 70, 98
tiles, 118
over, 118
under, 118
tiling, 118-120
Spars, 52, 54, 106, 111, 114, 118, 121, 126, 129, 130
Spearpoint floor clips, 38
Species, timber, 1, 17-24
Spelter, 132
Spindle moulder, 29, 87
Spiral grain, 4, 17, 18
Splayed scarf joint, 56
Split shingles, 126
Splitting, 8, 10, 102, 126
Spraying preserving process, 14
Sprigs, 66, 68
Spring-trees, 78, 80, 83, 87, 88, 93, 96
warping, 8
wood, 2, 5, 7
Sprocketed eaves, 106, 109, 114
Spruces, 1, 2, 18, 19
Square roll, copper, 130
Stacking timber, 8, 10, 11
Staging, 57
Staircase, 78, 79
Stairs, 78-97
balustrades, 78, 80, 88, 90, 93, 95, 97, 102
open, 78, 80, 88, 90, 93, 95, 97
solid, 78, 80, 90, 93, 95, 102
classification, 79
bifurcated, 79
continuous, 79

Stairs—contd.
classification—contd.
geometrical, 79
circular, 79
elliptical, 79
winding, 79
newel, 79, 87-90, 93-97
straight flight, 79, 82-87
turning, 79
half-turn, 79, 80, 82-95
dog-leg, 78, 79, 97-93
open well, 79, 80, 93-95
quarter-turn, 79, 95, 96
three-quarter-turn, 79
construction, 83, 84, 87, 90, 97
design, 82
essential requirements, 80, 82-84
landings, 78-80, 82-84, 88, 93
half-space, 79, 80, 88, 90, 93
quarter-space, 78, 80, 82, 93
steps, 78, 80, 82-84, 87, 90, 93, 96, 97
balancing, 78, 80, 82
bull-nosed, 80, 93, 96
commode, 78, 80
construction, 83, 84, 87, 97
curtail, 80, 97
dancing, 78, 80, 82
diminished, 80
fliers, 80, 83, 84, 87, 90, 93
kite, 80, 96
proportions, 82
scroll, 80
splayed, 80, 87, 93, 96
winders, 78, 80, 82, 95, 96
strings, 78, 80, 83, 84, 87, 88, 90, 93, 96, 97
close, 80, 83, 84, 87, 88, 90, 93, 96
cut, 80, 97
housed, 80, 83, 84, 87, 88, 90, 93, 96
notch boards, 80, 97
open, 80, 97
rough, 78, 80, 83, 87, 88, 93, 96
terms, 78-80
Stair trencher, 84, 85
Stairway, 80
Standard asbestos-cement corrugated sheets, 124
Standing seams, 130-132
Stand-up welts, 130-132
Staples, thatch, 134
Staves, 72
Steam pipes, 10, 11
Steel angles, 34
bars, 36, 43, 45, 47, 48, 52, 84
beams, 31, 32, 34-36, 52
sizes, 32, 34, 35
expanded metal, 36
plates, 53, 56
purlins, 122, 124
roof trusses, 54, 56

Steel—contd.
stainless, 84, 103
windows, 74, 76, 78, 93
Steeping preserving processes, 13, 14
cold, 14
hot, 14
hot-and-cold, 13
Kyanizing, 14
Powellizing, 14
Stemming, 58
Sticks, piling, 8, 10, 102
Stiles, 66, 70, 88
Stockboard, 112
Stone coping, 116
lintel, 31
pads, 31, 34, 52
slating, 124-126
abutments, 126
eaves, 125
hips, 126
ridge, 126
valleys, 126
verges, 126
Stoothed partitions, 42, 43, 48, 49, 51, 52, 84, 88, 90, 93
Stoothings, 42, 43, 48, 49, 51, 52, 84, 88, 90, 93
Storey rod, 80, 84, 90
Stout heart boards, 98
Straight grain, 4, 5, 17-24, 126
Straining beams, 43, 54, 56
piece, 43
sill, 54, 56
Straps, wrought iron, 43-45
Strength, timber, 17, 102
Stretchers, 60
Striking plate, 76
Strings, copper, 180
Stringers, 78, 80, 83, 84, 87, 88, 90, 93, 96, 97
Stripe figure, 5, 21, 23, 24
Strip flooring, 36
lathing, 114
Structure, wood, 1-5
hardwoods, 2-4
fibres, 4
parenchyma, 4
pits, 2
pores, 2, 4, 5, 19, 20
rays, 2, 4, 5, 19-24
vessels, 6
softwoods, 2-4
parenchyma, 2
pits, 2
rays, 2
resin ducts, 2, 4, 18
tracheids, 2, 4
Struts, 43, 52-54, 56-58, 60, 62
Strutting, floor, 31, 49
Stub-tenoned joint, 42, 43, 66, 93, 95

Stuck mouldings, 63
Stud partitions, 42, 43, 48, 49, 51, 52, 84, 88, 90, 93
Studs, 42, 43, 49, 52, 84, 88, 90, 93, 110, 111
Stumps, 5, 98
Sub-floor, concrete, 38, 41
wood, 38, 40, 41
Sugar maple, 5, 22, 38, 40, 101
pine, 18
Summer wood, 2, 5, 7
Sump, 58
Superficial preserving processes, 14
brush application, 14
dipping, 14
spraying, 14
Superimposed loads, 32, 34, 35
Surface checking, 8
planing and thicknessing machine, 28
Surfacing floors, 28-30, 40, 102
Suspended ceiling, 49
Swage saw, 26
shaper, 26
Swedish pine, 1, 2, 5, 18, 36, 38, 106, 110, 111
Sweet chestnut, 5, 20
Swelling, 7, 40
Swept valleys, 106, 109, 110, 126, 129
Sycamore, 5, 23, 70, 98, 101
Syllabus, Building Construction, 136


## T


Tabling, 127
Tailstock, 30
Tangential shrinkage, 7, 102
Tannin, 2
Tant, 125
Taping machine, 100
Tasmanian myrtle, 22
oak, 23, 38
Teak, 5, 21, 23, 34, 38, 126
African, 21, 38
Rhodesian, 5, 24, 38
Templets, 63, 79, 84, 87
riser, 79, 84
tread, 79, 84
Temporary timbering, 56-62
centering, 60-62
trenches, 56-60
Tenoning cutterblocks, 29, 30
machine, 29
Tensioning saw blades, 27
Tension rods, 43
stress, 32, 62, 102
Tentest, 49
Terms, stairs, 78-80
Terra-cotta block and brick partitions, 45
Test-piece, timber, 10

Tests, floor, drying, 38
tiles, 105, 120
freezing, 105
permeability, 105, 120
transverse, 105, 120
Texture, tiles, 105
timber, 4, 5, 18-23
coarse, 5, 21, 23
even, 5, 18, 20-23
fine, 5, 19, 20
medium, 5, 19
uneven, 5
Thatch, 133, 134
Thermacoust slabs, 47, 49
Thermometer, dry and wet bulb, 10, 11
Thicknessing, 28-30
machines, 28, 30
Three-light cased windows, 74
quarter-turn stairs, 79
Thresholds, 63, 66
Through checking, 8
Thwacker, 112
Thwacking frame, 112
Tie beams, 53, 54, 56, 62
Tight-cut surface, plywood, 100
Tile battens, 106, 109, 110, 111, 114
creasing, 110, 116, 120
galleting, 114, 116, 118
hanging, 110-112
insets, 109, 114, 120
nails, 106, 110, 114, 118, 121
tongues, 109
undercloaks, 111, 112, 114, 118, 122, 126
Tiles, 52, 56, 104-120, 122
angle, 111
asbestos-cement, 122
Basilican, 116-118
bonnet, 109
concrete, 120
cone, 109, 116, 120
eaves under, 105, 106, 110, 114, 118, 122
half-round, 109, 112, 116, 118, 121, 122, 124, 126
hand-made, 104-106, 110, 112, 116, 118
hog-back, 109
interlocking, 120
Italian, 116-118
double Roman, 118
old Roman, 116, 118
over, 116
under, 116
single Roman, 118
machine-made, 104, 105, 112, 120, 122
pantiles, 56, 112-116, 122
plain, 52, 104-112, 114
eaves under, 105, 106, 110, 114, 118
ridge under, 105, 109
tile-and-a-half, 106, 109-111
Tiles—contd.
purpose-made eaves, 122
hip, 109
verge, 116, 118, 120, 122
valley, 116, 122
Roman, 116-118
segmental, 120
Spanish, 118-120
over, 118, 120
under, 118, 120
"Turnall" Trafford, 122
Tiling, 104-112, 114, 116-118, 120
Basilican, 116-118
Italian, 116-118
pantiling, 112-116
plain, 104-112
Roman, 116-118
Spanish, 118-120
vertical, 110-112
Tilting fillets, 106, 116
Timber, 1-31
characteristics, 17-24
classification, 1, 17-24
conversion, 4-6, 98, 100
defects, 4, 7, 8, 10, 14-17, 38, 40, 41, 51, 100, 103, 130
figure, 4, 5, 17-24
fire-retarding, 14, 126
floors, 31-43, 45, 48-51
grain, 4, 5, 17-24
hardwoods, 1-5, 19-24
identification, 4
liners, 45, 47, 51
partitions, 42-51, 52, 84, 90, 93, 101
preparation, 24-30, 96
preservation, 12-15
roofs, 51-56
seasoning, 7-12, 38, 100, 102
softwoods, 1, 2, 4, 5, 7-9, 12, 13, 17-19, 26, 36, 38, 40, 41, 56, 70, 98, 106, 110, 111
sources, 1, 17-24
stacking, 8, 10, 11
strength, 17, 102
structure, 1-5
texture, 4, 5, 18-23
uses, 17-24
weight, 7, 17-24, 32, 34, 35
Tinted glass, 66, 68
Tongued and grooved joint, 36, 40, 45, 47, 58, 63, 70, 72, 80, 83, 84, 87, 88, 96, 114, 130
grooved and dovetailed, 38
mitred joint, 36
Tongues, 66, 70, 72, 96
Tonguing, 29, 30
head, 29
Torching, 106, 126
Tracheids, 2, 4
Transomes, 63, 66
lights, 63, 66
Transverse bars, 36
test, tiles, 105, 120
Travelling carriage, 6
table, 6
Treads, 29, 79, 80, 82, 84, 87, 88, 90, 95
Trenching, 29, 83, 84, 87
Trimming, plywood boards, 100, 102
Trinidad cedar, 20
Triple floors, 34-36
Trucks, 10, 11
Trussed partitions, 43-45
purlin, 52
Tucking boards, 57
Tunnel kiln, 11
"Turnall" Trafford tiles, 122
Turning stairs, 79
Tusk tenon joint, 88
Twin pantiles, 122
Twist, 8

U

Undercloaks, tile, 111, 112, 114, 118, 122, 126
Undercut roll, 130
Under tiles, 105, 106, 110, 114, 116, 118, 120-122
Uneven grain, 4
texture, 5
Universal woodworker, 30
Untearable felt, 106, 114, 118, 126
Uses, timber, 17-24

V

Valley boards, 110, 116
Valleys, 106, 109, 110, 118, 120, 126, 134
circle, 109, 110, 126
copper, 132
laced, 106, 126
lead, 110, 116, 129
purpose-made, 110
swept, 106, 109, 110, 126, 129
thatched, 134
Vegetable glue, 101
Veneers, 6, 40, 70, 72, 96-113
slicing, 98, 100
Venetian arch centre, 60
Ventilation, floors, 15, 16
holes, doors, 68
Verges, 106, 111, 112, 114, 116, 118, 120, 126, 134
thatched, 134
Vertical battens, 118
grain, 4-7, 22, 38, 100, 126
log band mill, 6
shingles, 127-129
slating, 112
spindle moulding machine 29, 87
tiling, 110-112
veneer slicer, 98
Vessels, 2, 4, 5, 19-24
Victorian oak, 23, 38
V-shaped ridge, 109
Vulcanizing, 41

W

Wainscot oak, 22
Walings, 56-58, 60
Walking line, 80, 95
Wall boards, 48, 49, 54, 84, 120, 129
plates, 83, 106
Walnut, 17, 21, 24, 40, 70, 98, 102
African, 24
American black, 24
Australian, 24, 102
Benin, 24
Black sea, 24
Circassian, 24
East Indian, 21
English, 24
European, 24
French, 24
Italian, 24
Nigerian, 24
Queensland, 24, 102
Warping, 8, 10, 40, 102, 103, 130
bow, 8
cup, 8, 40
spring, 8
twist, 8, 102
wind, 8
Washing-off frame, 112
Water closet, 93
Waterproofed mortar, 116
Wavy grain, 4, 5, 17, 20-24
Weather boards, 63, 66
tiling, 110-112
Wedges, 56-58, 60, 62, 83, 84, 87
Welded connections, 36, 74
Well, stair, 80, 93
Weight, asbestos-cement covering, 121
brickwork, 47
copper, 130
fibrous wood cement, 47
pantiles, 114
plain tiles, 114, 116
plaster, 32, 35
shingles, 126
timber, 7, 17-24, 32, 34, 35
ceiling joists, 35
floor boards, 32, 34
binders, 32, 35
joists, 32, 34
zinc, 132
Welted drips, 133
rolls, 130
Welts, copper, 130, 132
zinc, 133

Western hemlock, 17, 38
red cedar, 17, 126
white pine, 18
West Indian cedar, 20
mahogany, 5, 21, 70, 98
satinwood, 23, 98
Westminster Hall roof, 16
Wet-glued process, 100
Weymouth pine, 1, 2, 5, 18
White chuglam, 20, 70, 98
deal, 1, 19, 38
elm, 20
fir, 1, 19, 38
guarea, 20
lauan, 21
maple, 5, 22, 38, 40, 101
meranti, 22
oak, American, 22, 38
pine, 1, 2, 5, 18
seraya, 23, 38
spruce, 1, 18
Whitewood, 1, 19, 24, 38
American, 24
Baltic, 1, 19, 38
canary, 24
Widthing, 28
Winchester cut, tiling, 112
Wind, 8
Winders, 78, 80, 82, 95, 96
Winding stairs, 79
Window frames, 70, 72, 74, 76
sashes, 72, 74, 76, 78
Windows, types, 51, 52, 70-78
dormer, 52
double-glazed, 51
metal, 74, 76, 78, 93
segmental-headed cased, 72
semicircular-headed cased, 70, 72
three-light cased, 74
Wire-cut tiles, 104, 105, 112
Wire-cutting table, 104
Wired tiles, 120
Withies, thatch, 133
Wood bending, 63, 72, 97
mastic, 40, 93
rolls, copper, 130
zinc, 132, 133
sub-floors, 38, 40, 41
wool cement, 47
Working, 7
stresses, timber, 31, 32
Wrought iron straps, 43-45
water bar, 66, 72, 112
Wych elm, 20

X

*Xestobium rufovillosum*, 16
Xylem, 2

Y

Yang, 21, 38
Yellow birch, 20, 36
Yellow—contd.
deal, 1, 2, 5, 18, 36, 38, 106, 110, 111
meranti, 22
pine, 1, 2, 5, 18
Yew, 19

Z

Zinc roofing, 132, 133
cappings, 133
characteristics, 132
chloride, 12, 13, 16
clips, 132, 133
flashings, 133
joints, 132, 133
drips, 133
beaded, 133
welted, 133
welts, 133
wood rolls, 132. 133
manufacture, 132
sizes, sheets, 132

Digitized by:

ASSOCIATION
FOR
PRESERVATION
TECHNOLOGY,
INTERNATIONAL
www.apti.org
Australasia Chapter

**BUILDING
TECHNOLOGY
HERITAGE
LIBRARY**

https://archive.org/details/buildingtechnologyheritagelibrary

from the collection of:

Miles Lewis, Melbourne

funding provided by:

the Vera Moore Foundation, Australia